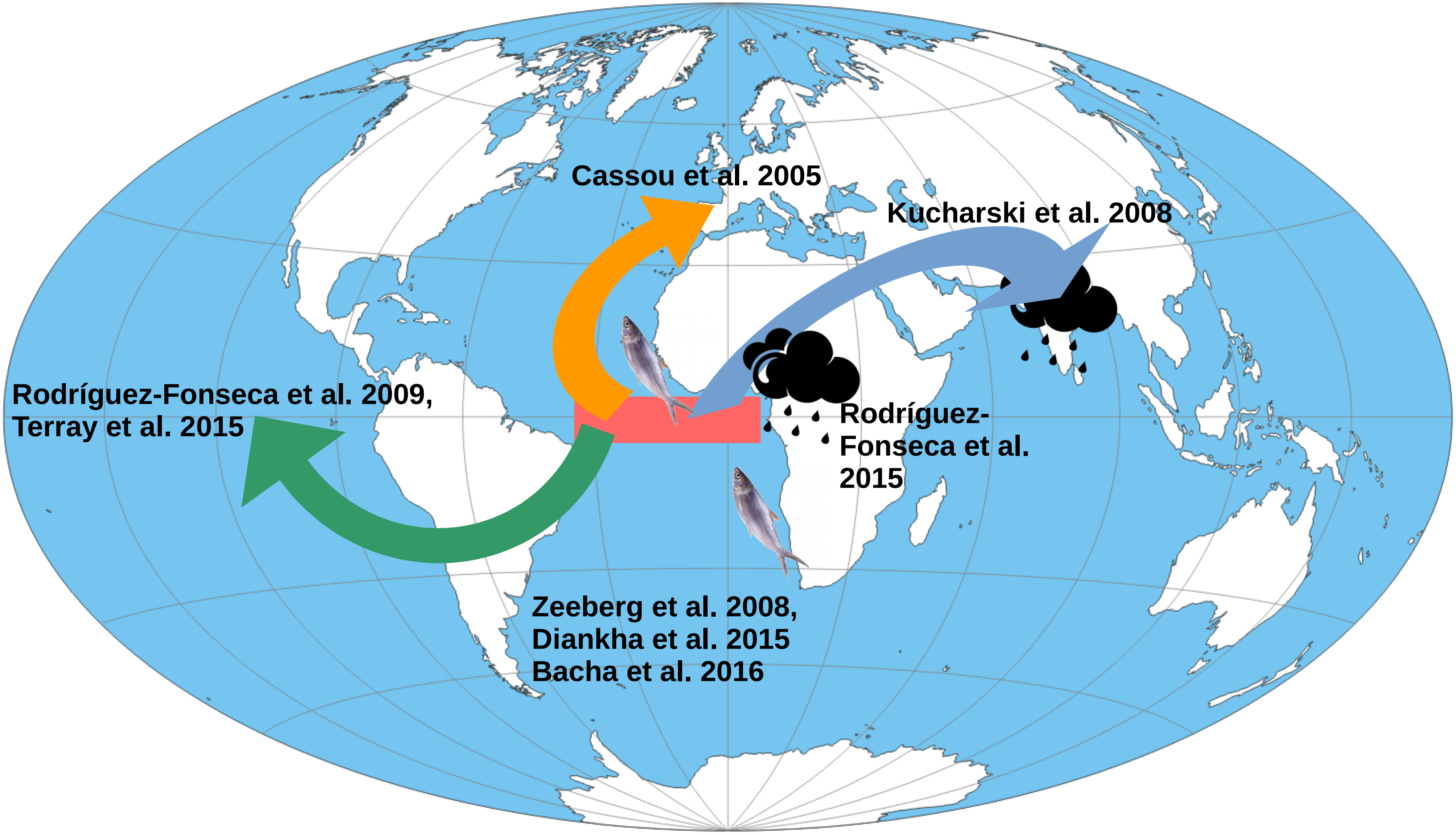
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Bias, variability and seasonal forecast in the Tropical Atlantic

Chloé Prodhomme and Eleftheria Exarchou,
Aurore Voldoire,
Anna-Lena Deppenmeier, Virginie Guemas, Francisco Doblas-Reyes

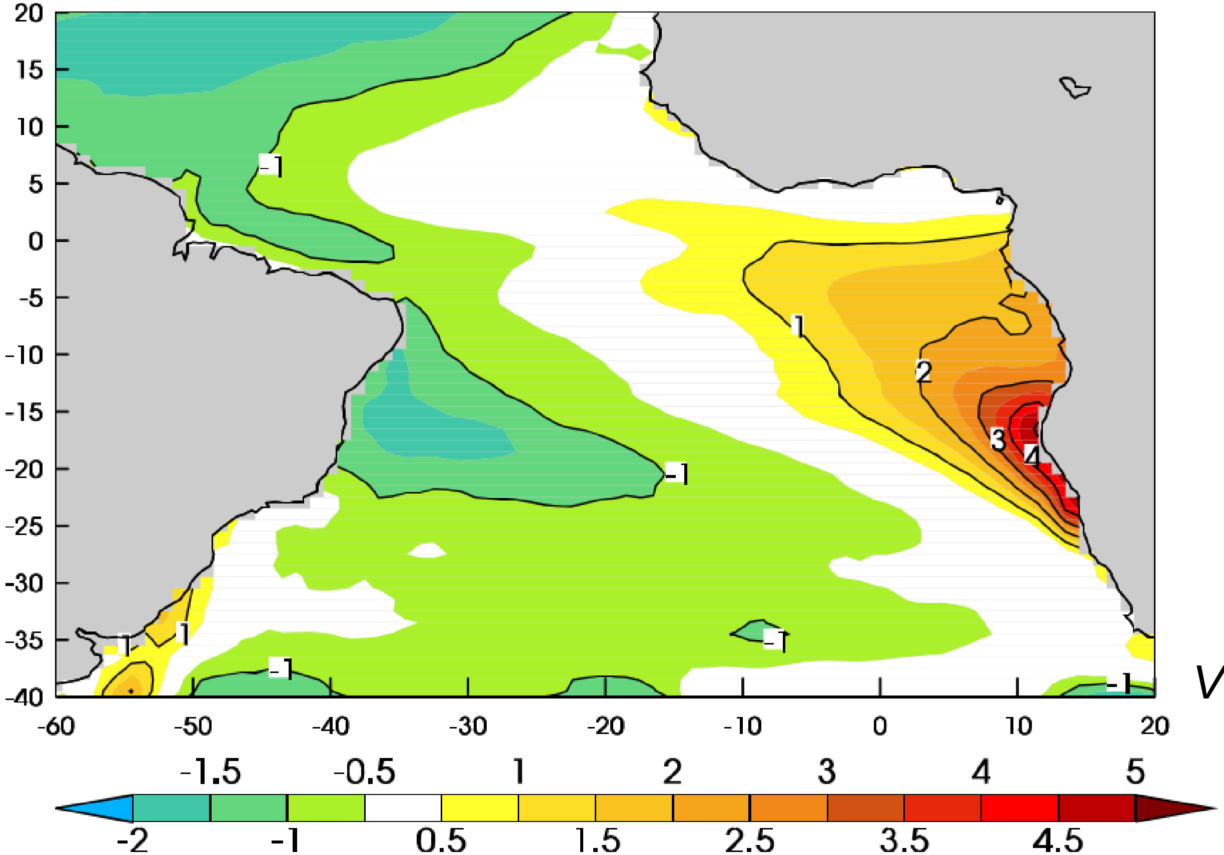
University of Bergen, 08th May 2017

Tropical Atlantic: A major area of impact



An area poorly simulated

CMIP5 Multi-Model Mean – HadISST



Voldoire et al. 2014

→ What are the mechanisms responsible of the formation of this bias?

→ How the presence of the biases is affecting the representation of the variability?

→ What is the predictability in the region and is the drift affecting it?

What are the mechanisms responsible of the formation of this bias?

Exarchou E., Prodhomme C., Brodeau L. Guemas V.. Doblas-Reyes F.J.: Origin of the warm eastern tropical Atlantic SST bias in a climate model. Under revision in Climate dynamics

Methodological approach

To assess model bias in EC-Earth3.1:

- Historical run at T511L91-ORCA025L75 **HR-Histo**, 1960-2000

To understand the development of bias and its time evolution as it grows from an initialized state

- Seasonal hindcasts, initialized every 1st May/November 1993-2009, 4 months long, 10 members

To assess the role of resolution

- Hindcasts at low (T255L91-ORCA1L46) high (T511L91-ORCA025L75) resolution: **LR-Hind** and **HR-Hind**

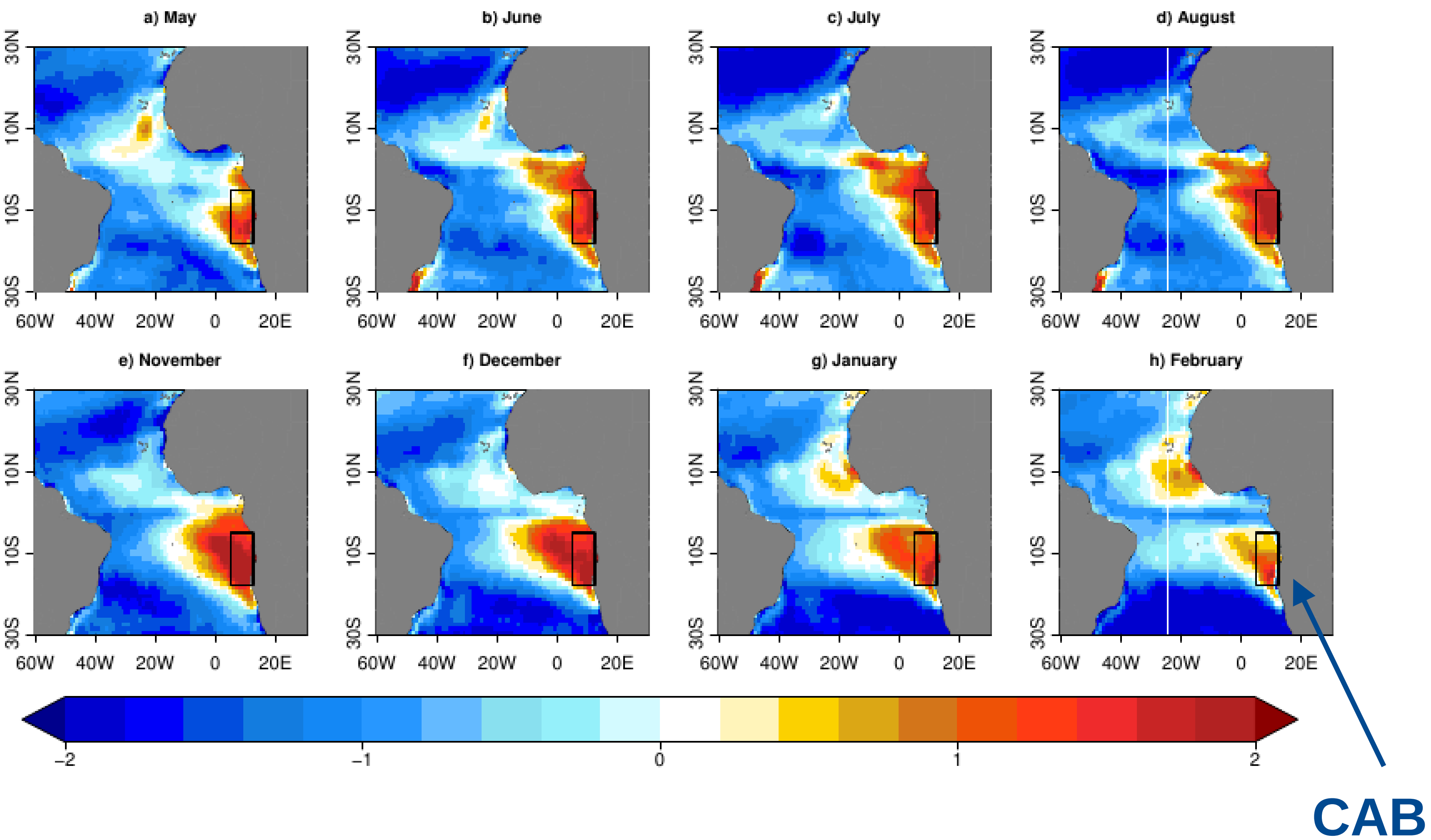
To evaluate the role of each model component and that of coupling

- Stand alone ocean and atmosphere simulations **LR-Ocean** and **LR-Atm**

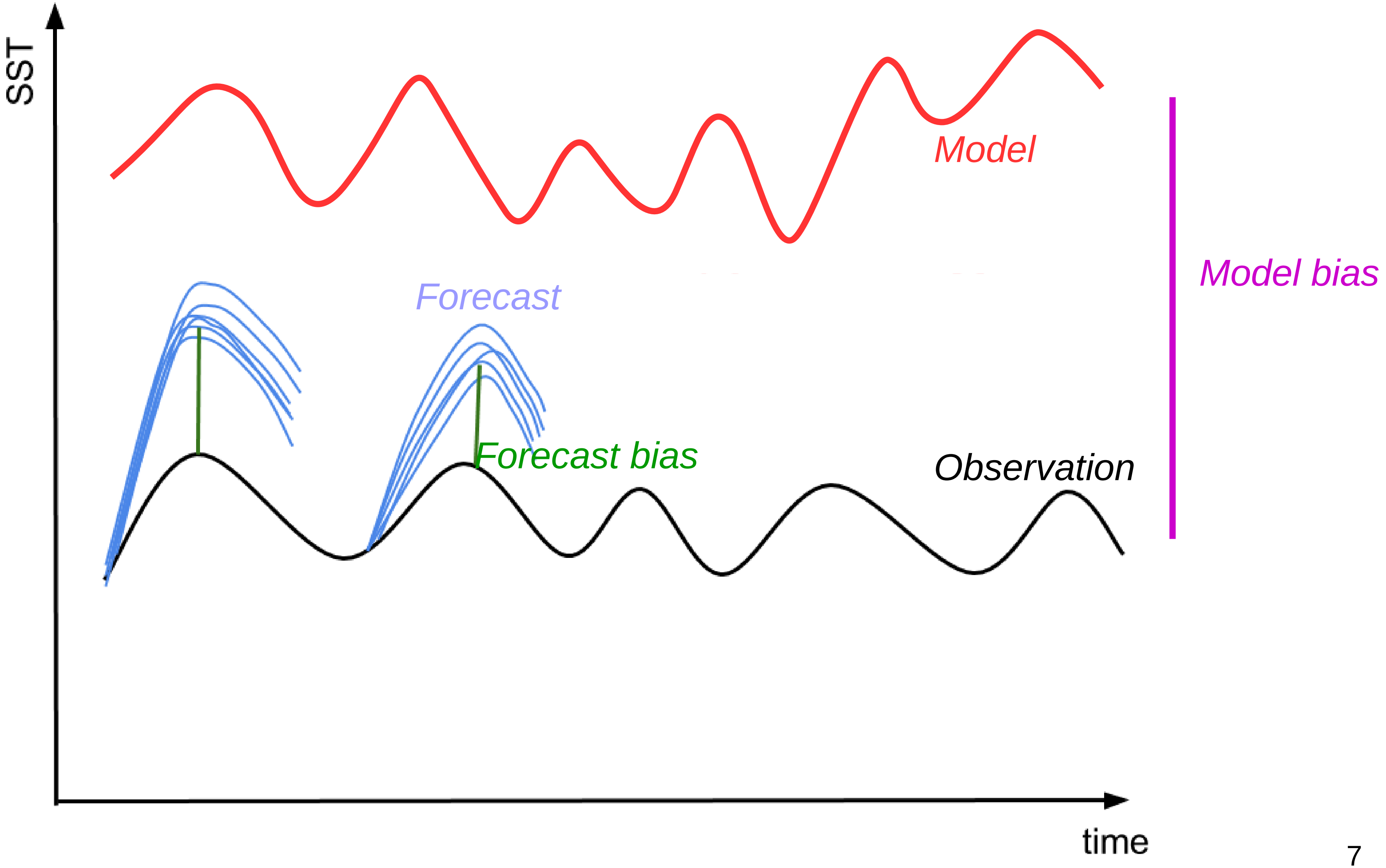
To assess different hypothesis formed at each step

- Additional sensitivity experiments **LR-Hind-wind**, **LR-Hind-Sol** and **LR-Hind-Dif**, (explained later)

SST bias in EC-Earth

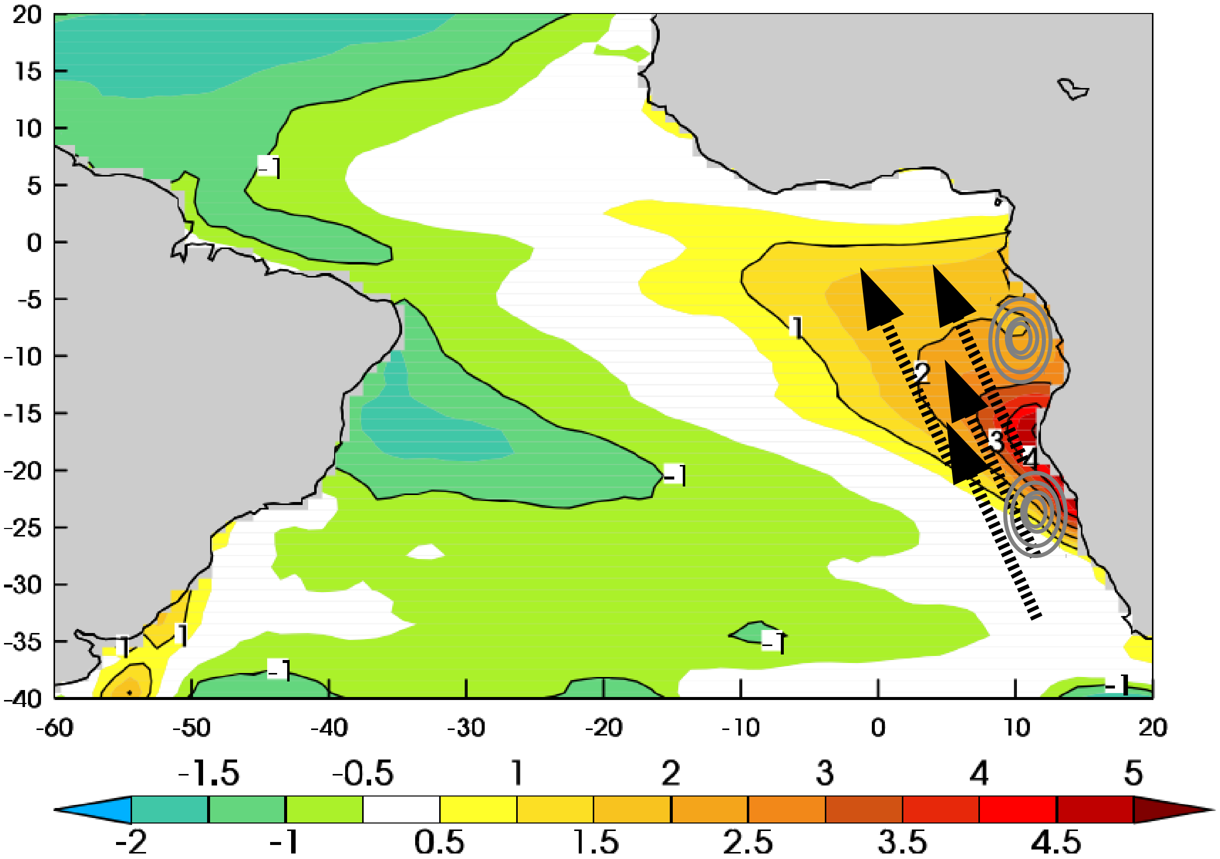


Some definitions...



Mechanisms identified

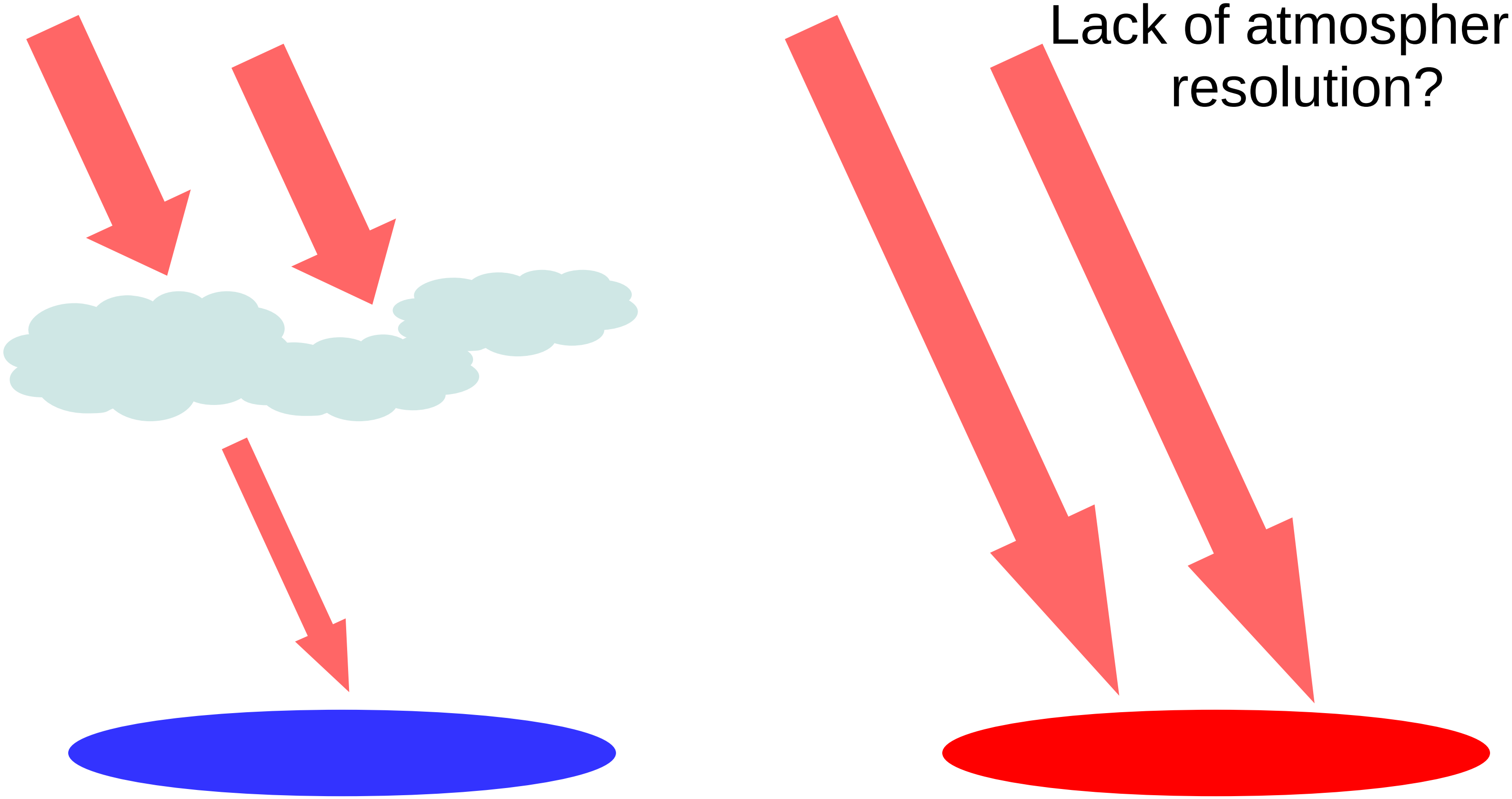
Weak alongshore wind and windstress curl
→ weak upwelling/vertical advection in the ocean



Lack of atmospheric resolution?

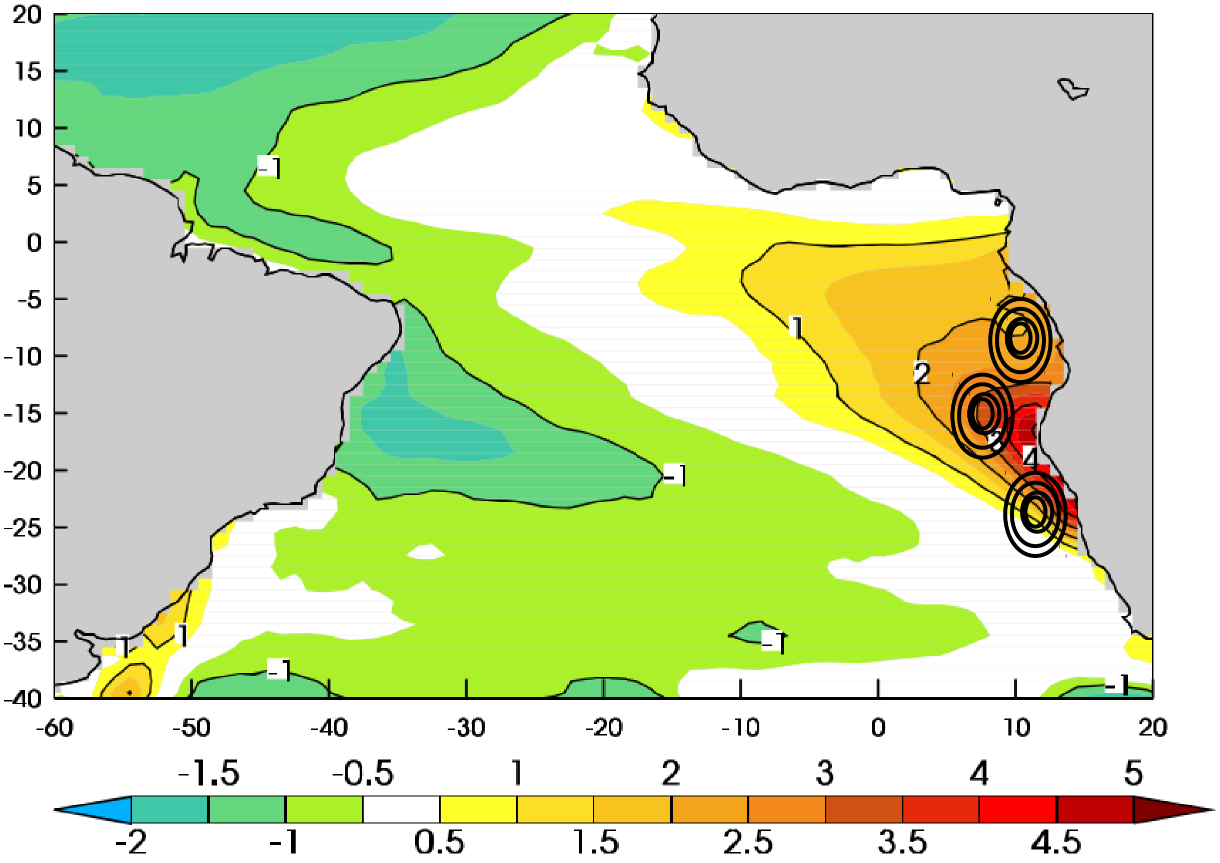
Mechanisms identified

Insufficient representation of low stratocumulus clouds at eastern boundaries
→ overestimation of solar insolation



Mechanisms identified

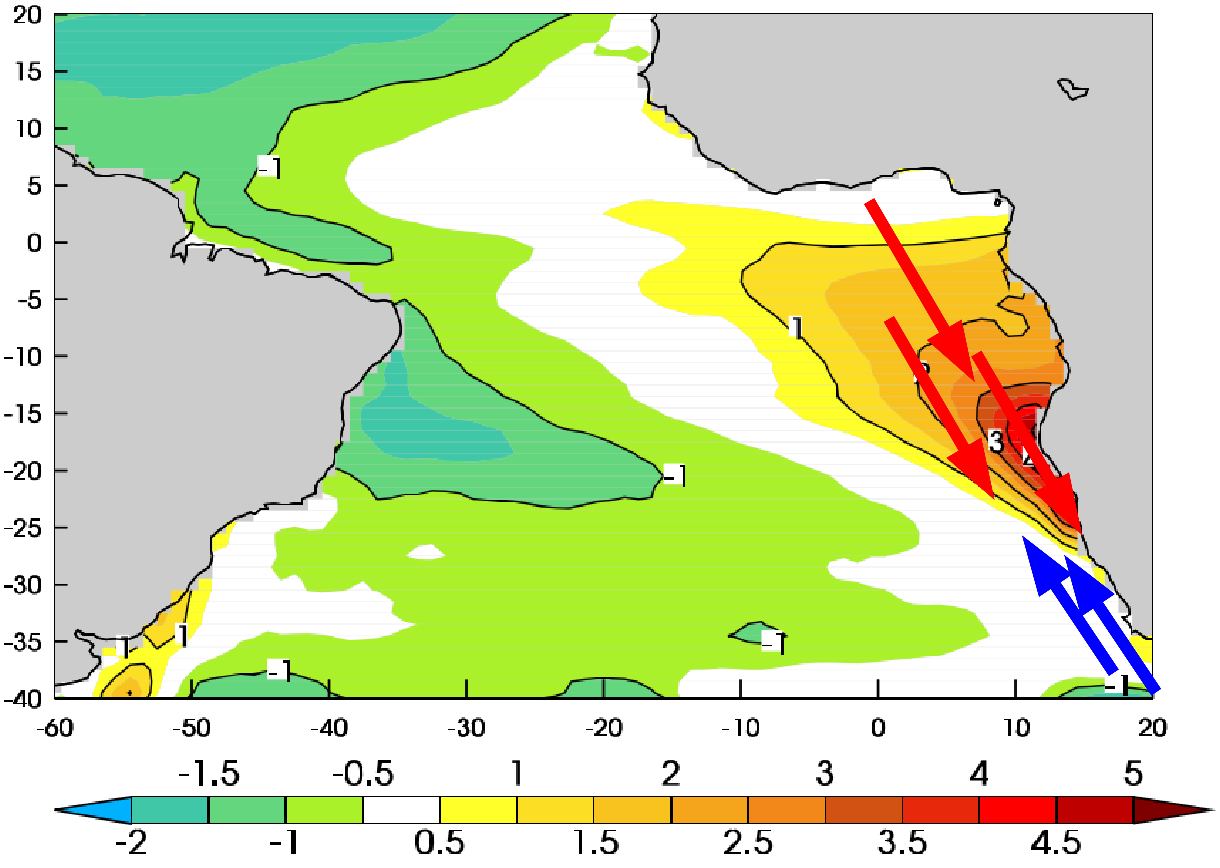
Insufficient mesoscale and sub-mescoscale ocean eddies
→ inadequate representation of eddies in the heat budget



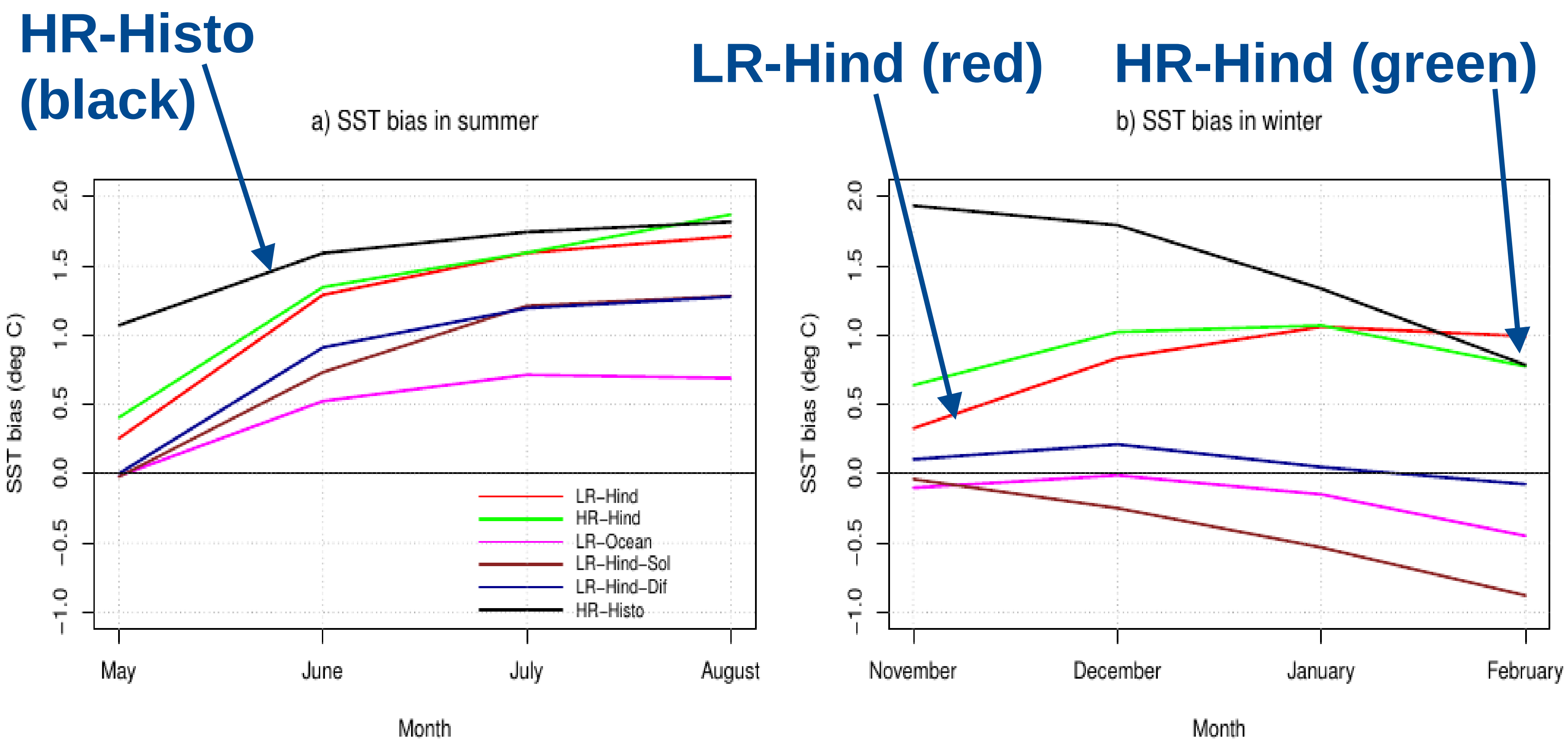
Lack of oceanic resolution?

Mechanisms identified

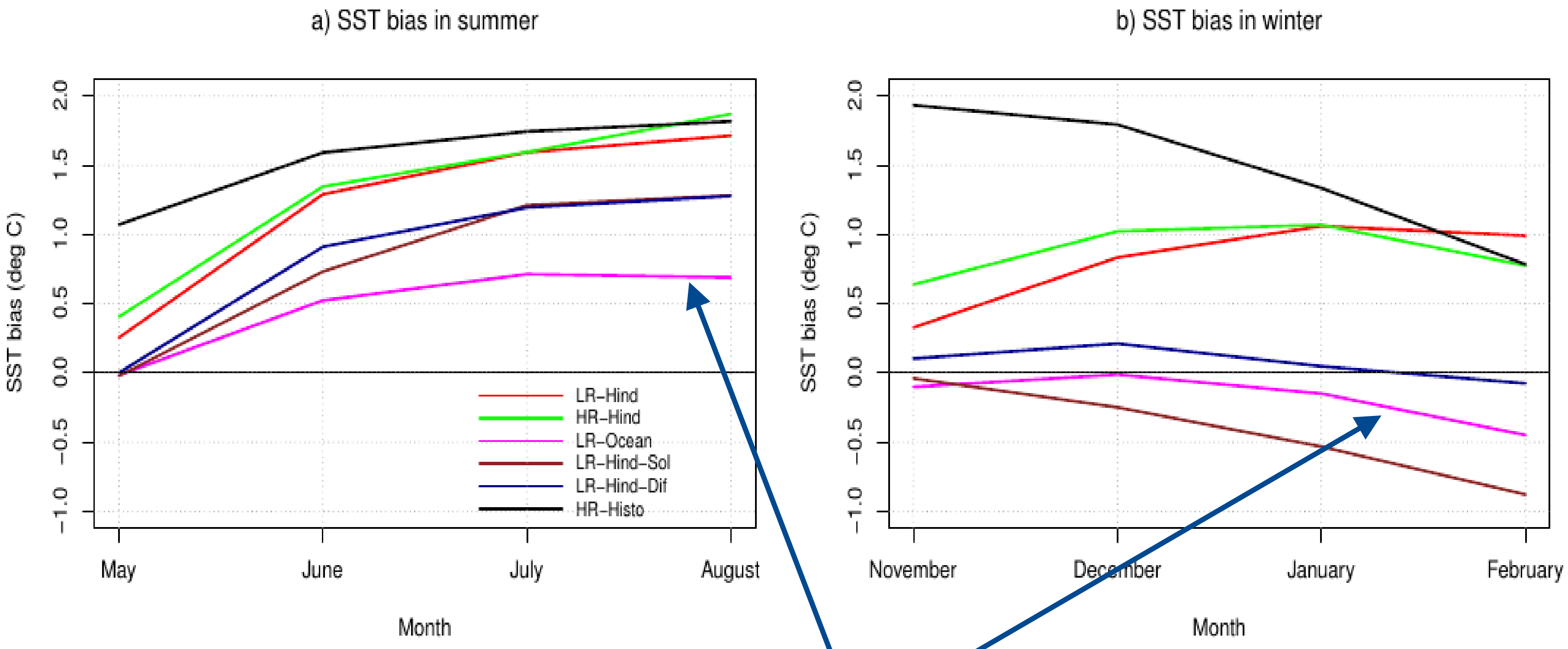
Southward displacement of a Angola Benguela surface front
→ weaker transports of cold water from the south to the South-East TA
→ stronger transport of equatorial warm water to the South-East TA



Bias development/Role of resolution



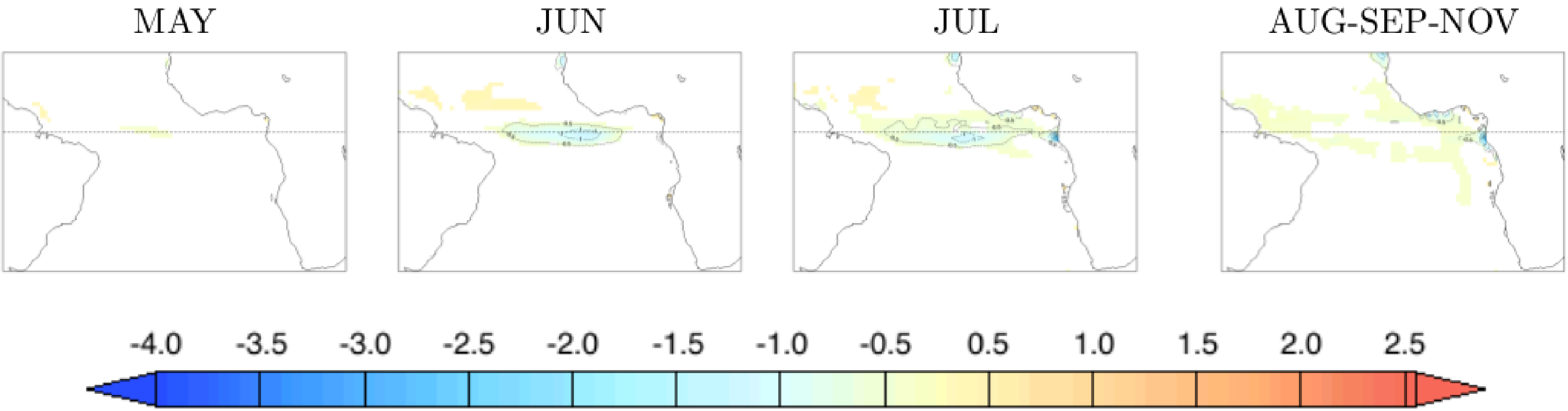
Role of ocean



LR-Ocean (magenta)

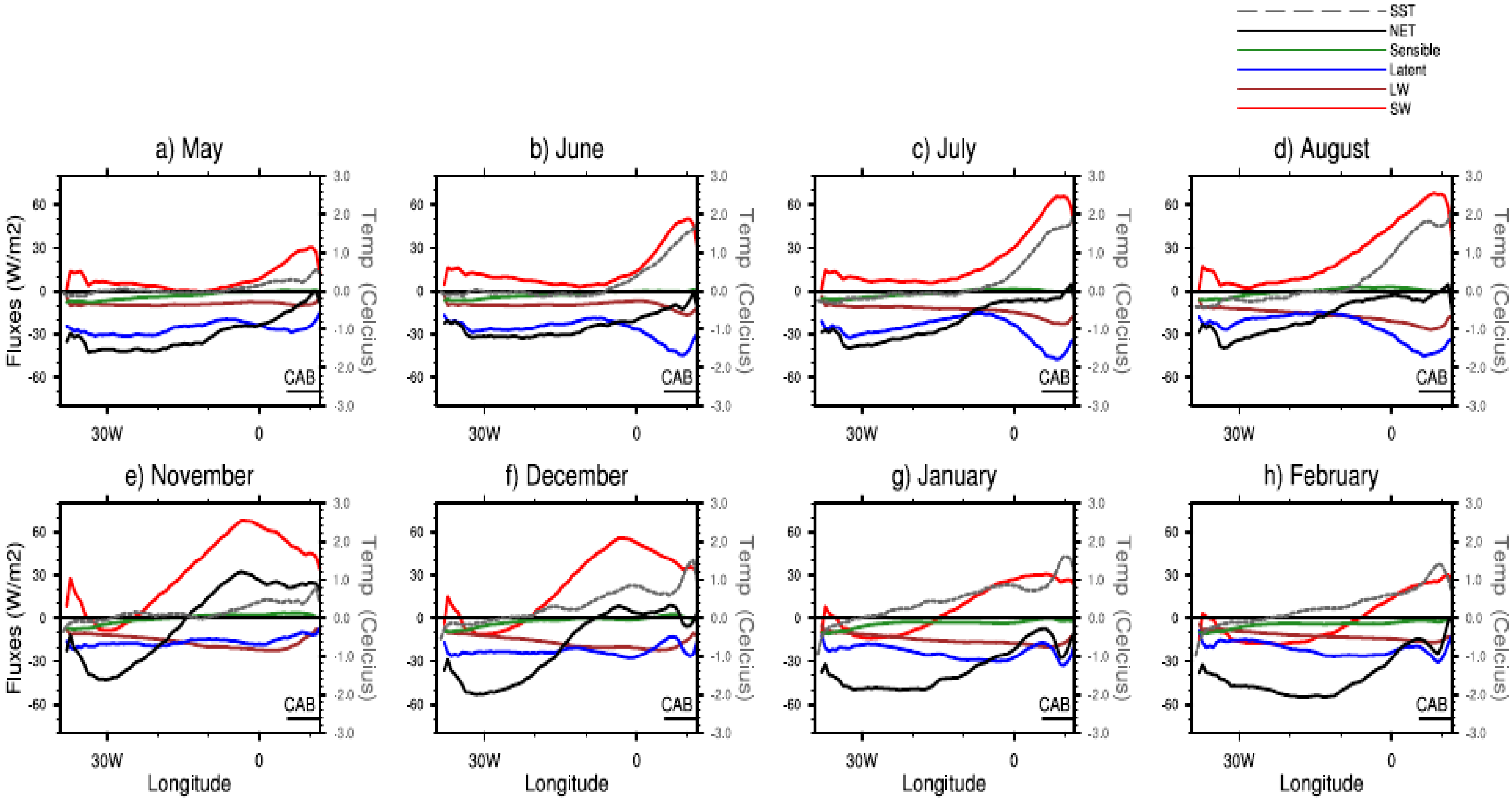
Role of wind stress

Corrected wind stress – LR-Hind



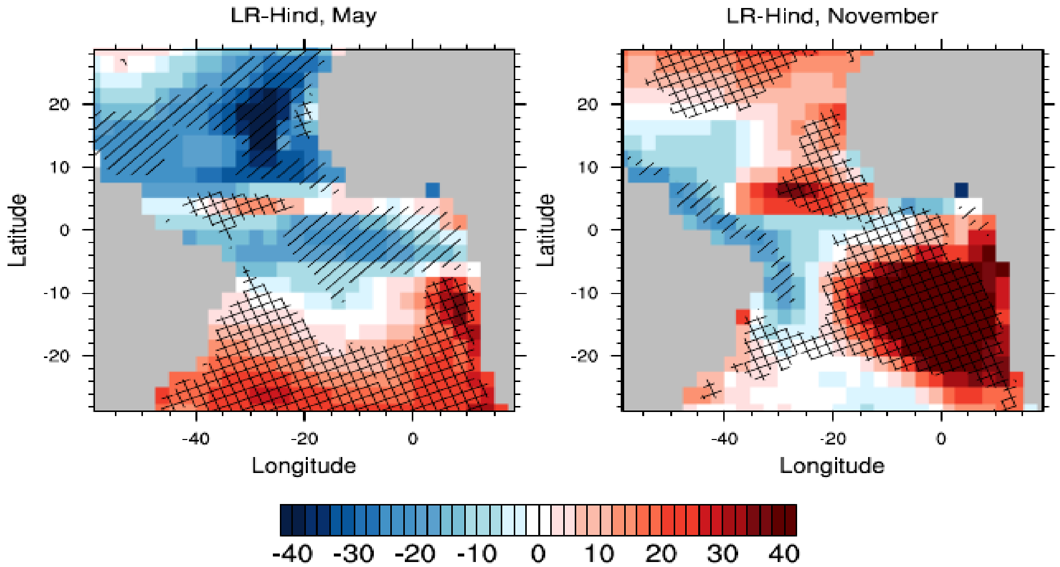
Courtesy to Aurore Voldoire and Thomas Toniazzo

Biases in surface heat fluxes

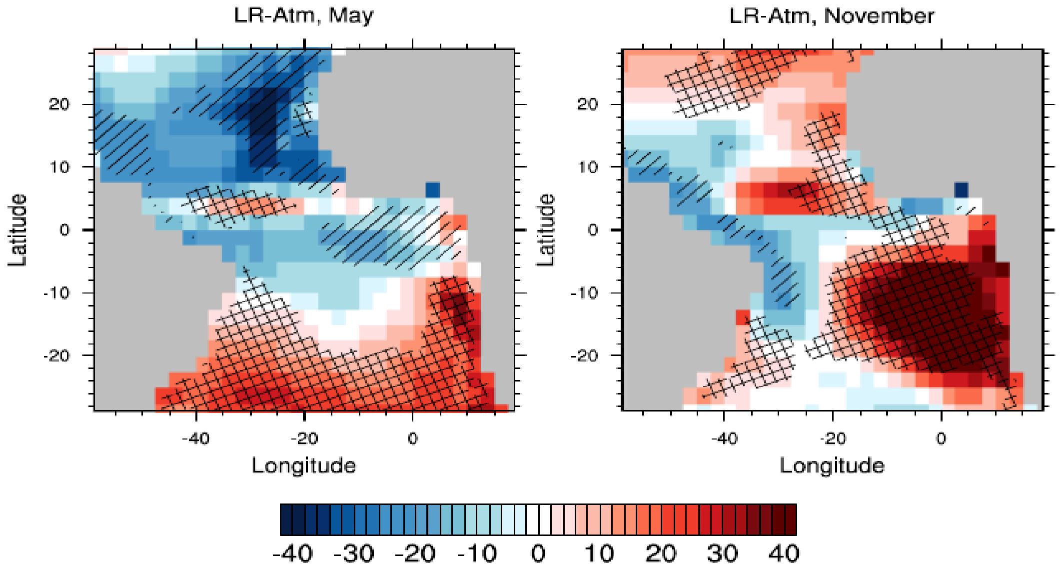


Origin of bias in solar fluxes

LR-Hind



LR-Atm

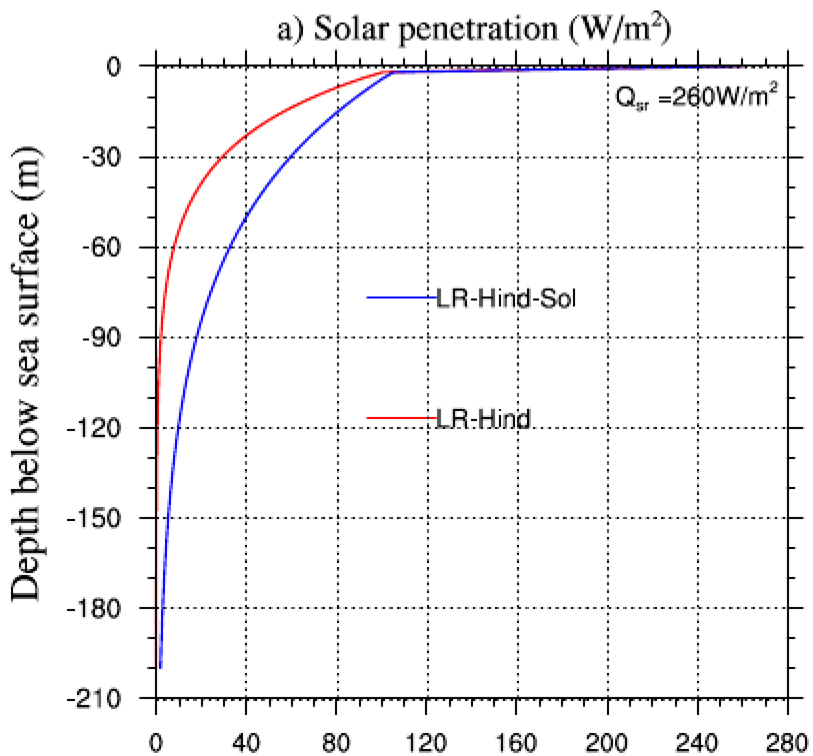


Role of solar penetration

Lengaigne et al. (2007)

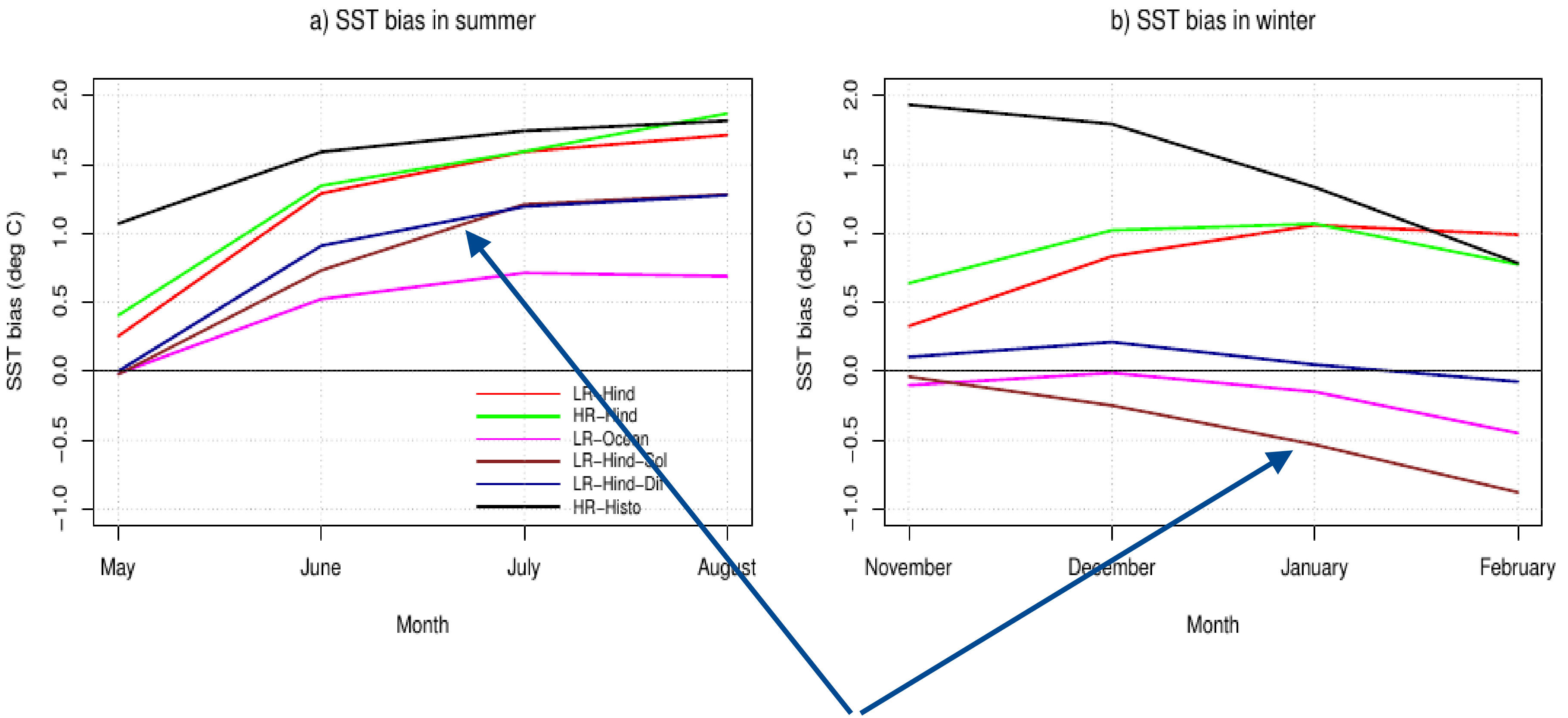
$$I_{pen}(z) = Q_{sr}(Re^{z/h1} + (1-R)e^{z/h2})$$

λ>700nm   400nm<λ<700nm



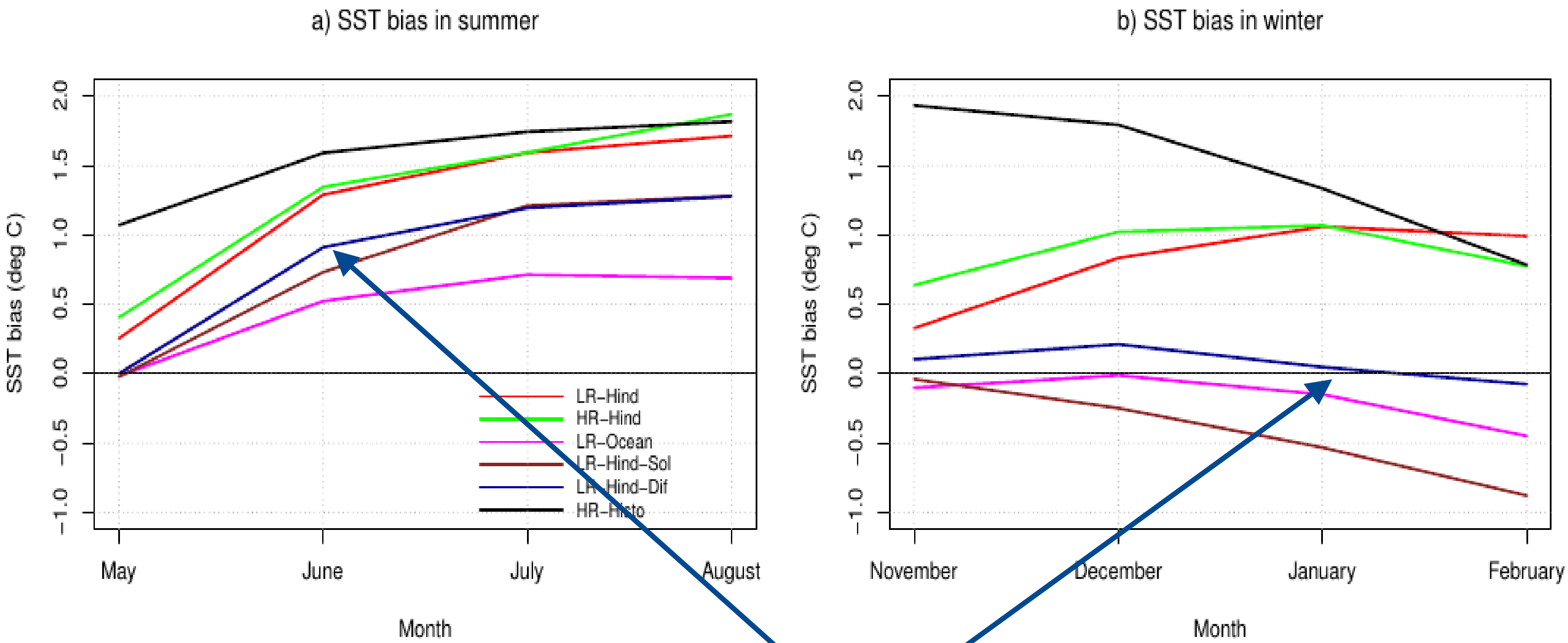
Solar penetration depth h2 increased from 23 to 50 m in LR-Hind-Sol (i.e. water more transparent due to less biological productivity)

Effect of less solar penetration in ML



LR-Hind-Sol (brown)

Effect of more turbulent mixing in ML



LR-Hind-Dif (blue)

Mechanisms

Less low stratocumulous clouds

Stronger solar fluxes at sea surface

Stronger net heat fluxes at sea surface (winter)

Overcompensation from latent heat fluxes leads to weaker net surface flux (summer)

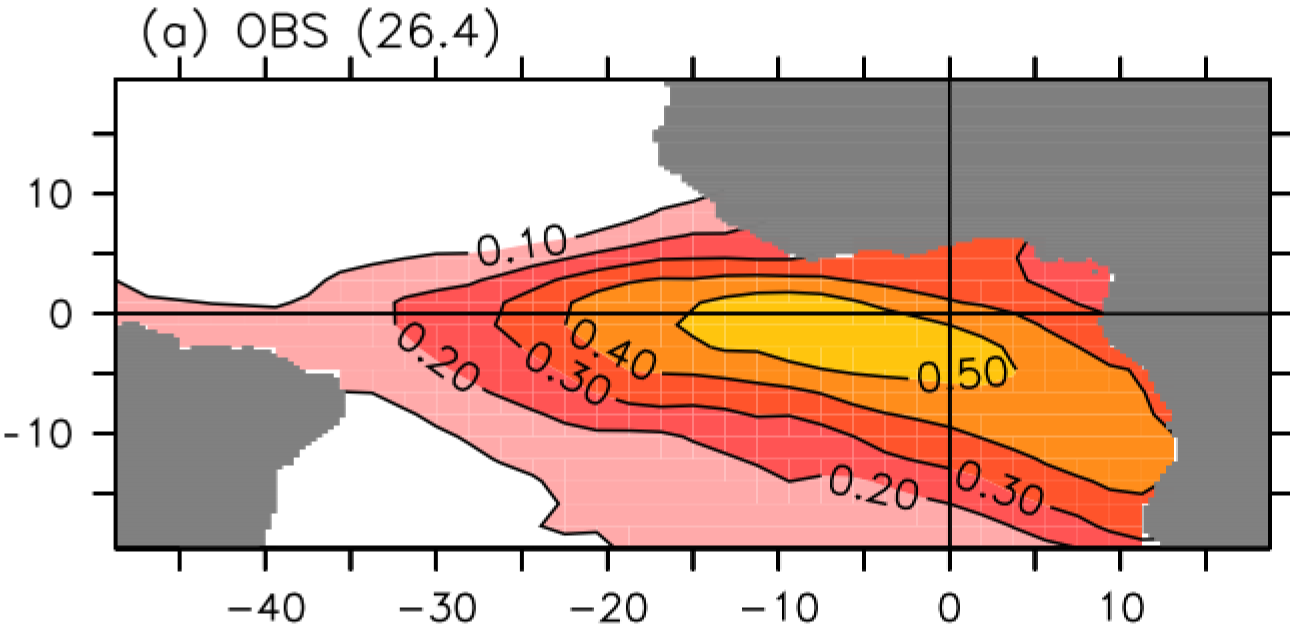
Excessive solar penetration (due to not representing the spatial patterns and the seasonal cycle of biological productivity) warms the mixed layer

Insufficient turbulent mixing of cold water to the mixed layer

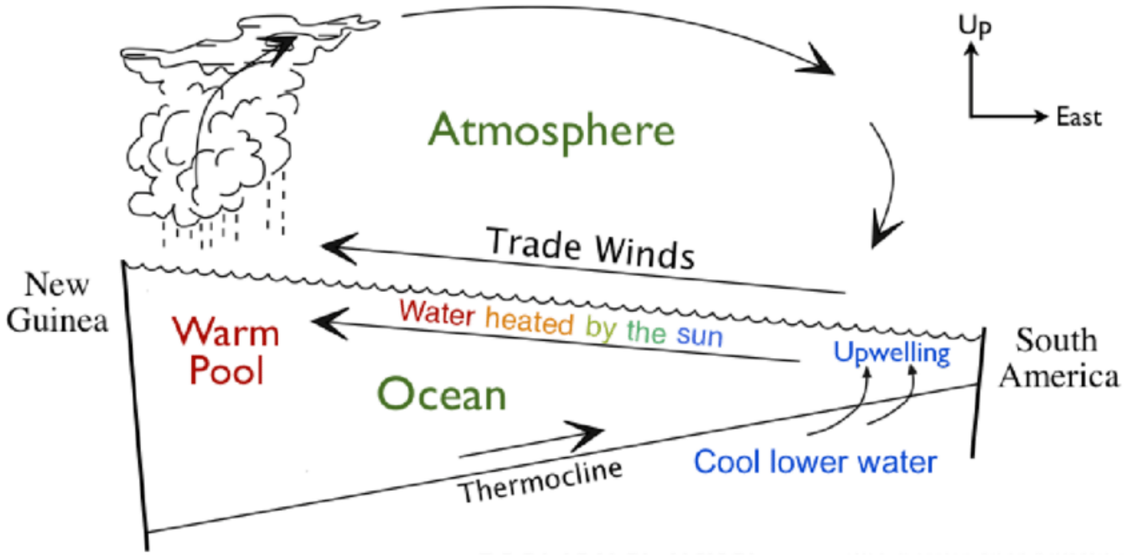
Warm SST bias

How the mean state representation controls the variability in the Tropical Atlantic?

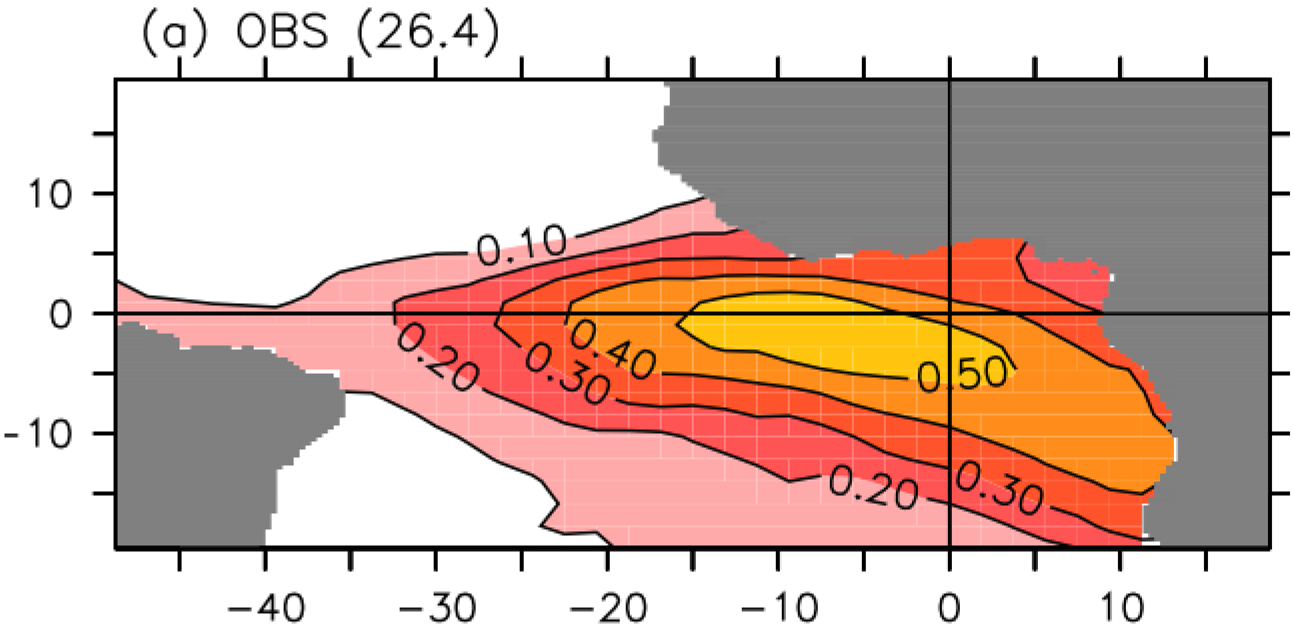
Atlantic Niño



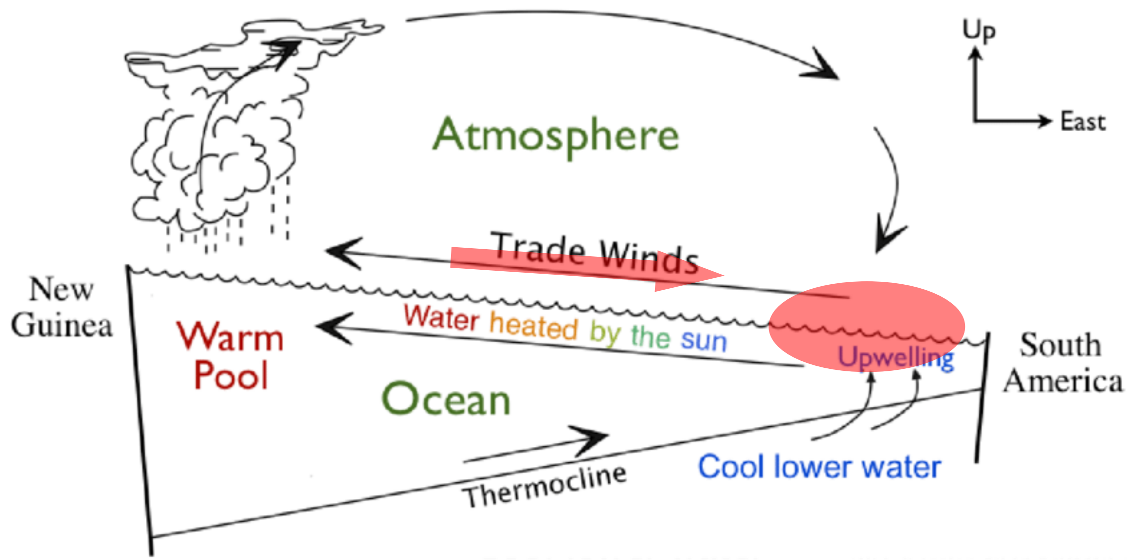
1st rotated EOF
in the Tropical Atlantic
(Ding et al. 2015)



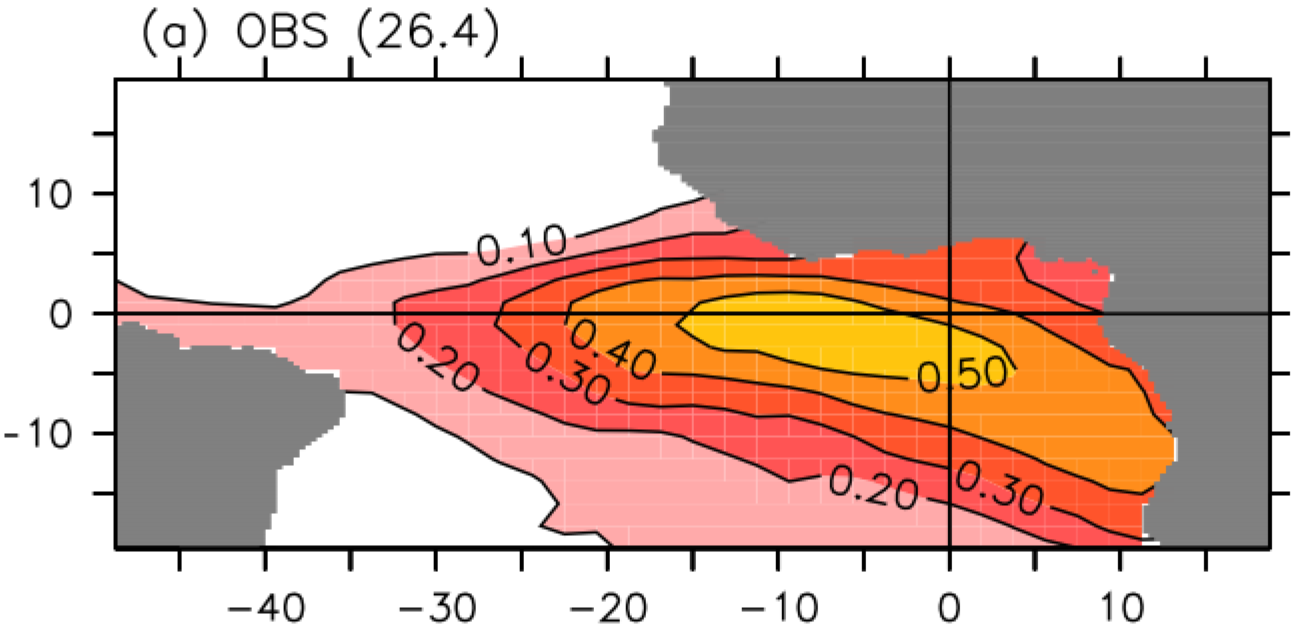
Atlantic Niño – Bjerknes Feedback



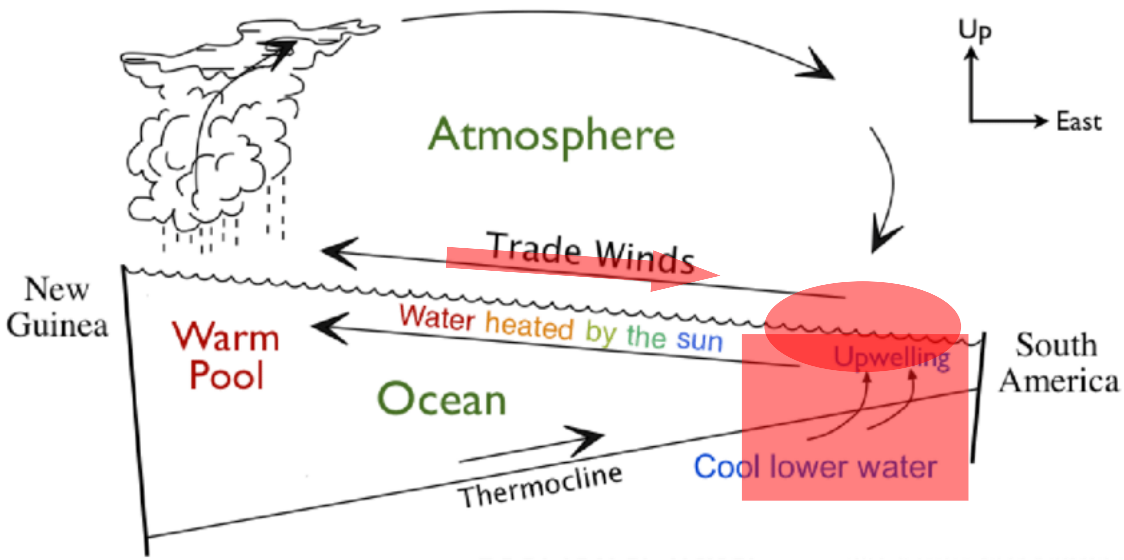
1st rotated EOF in the Tropical Atlantic *(Ding et al. 2015)*



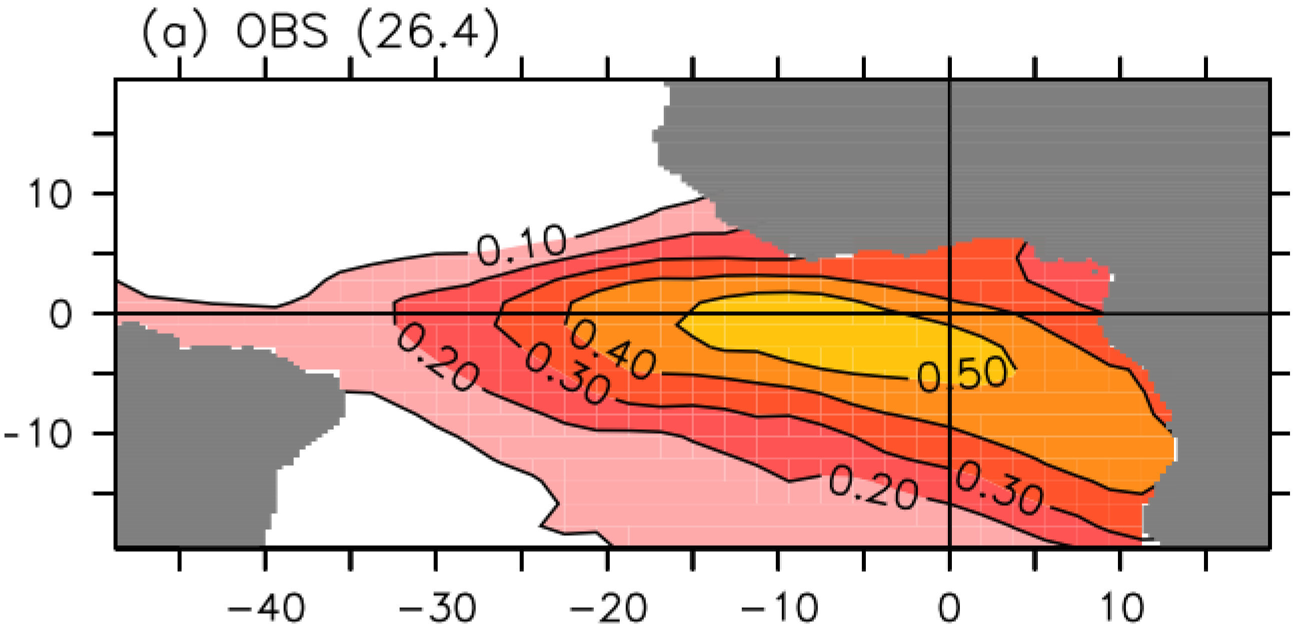
Atlantic Niño – Bjerknes Feedback



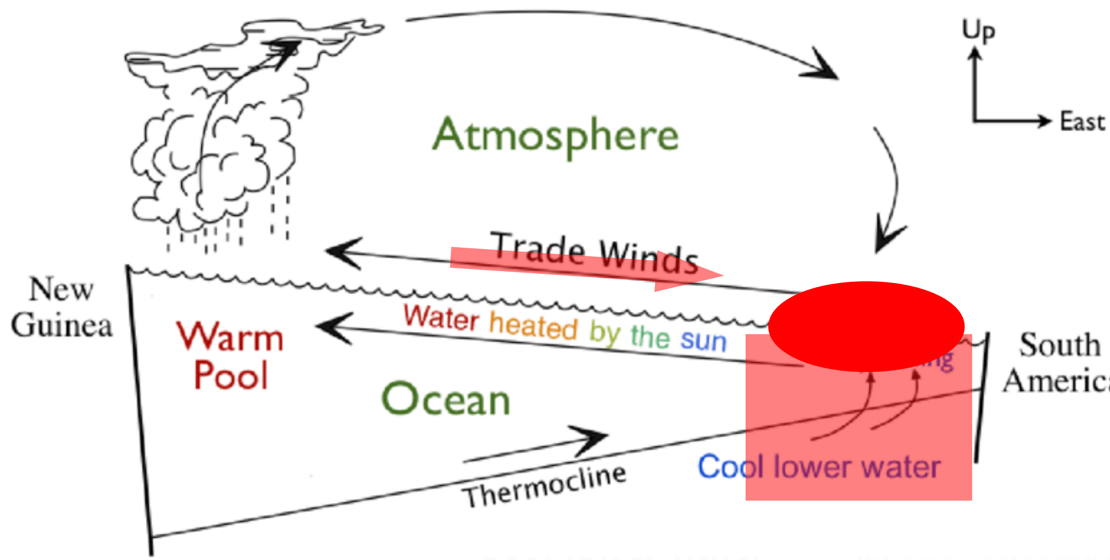
1st rotated EOF
in the Tropical Atlantic
(Ding et al. 2015)



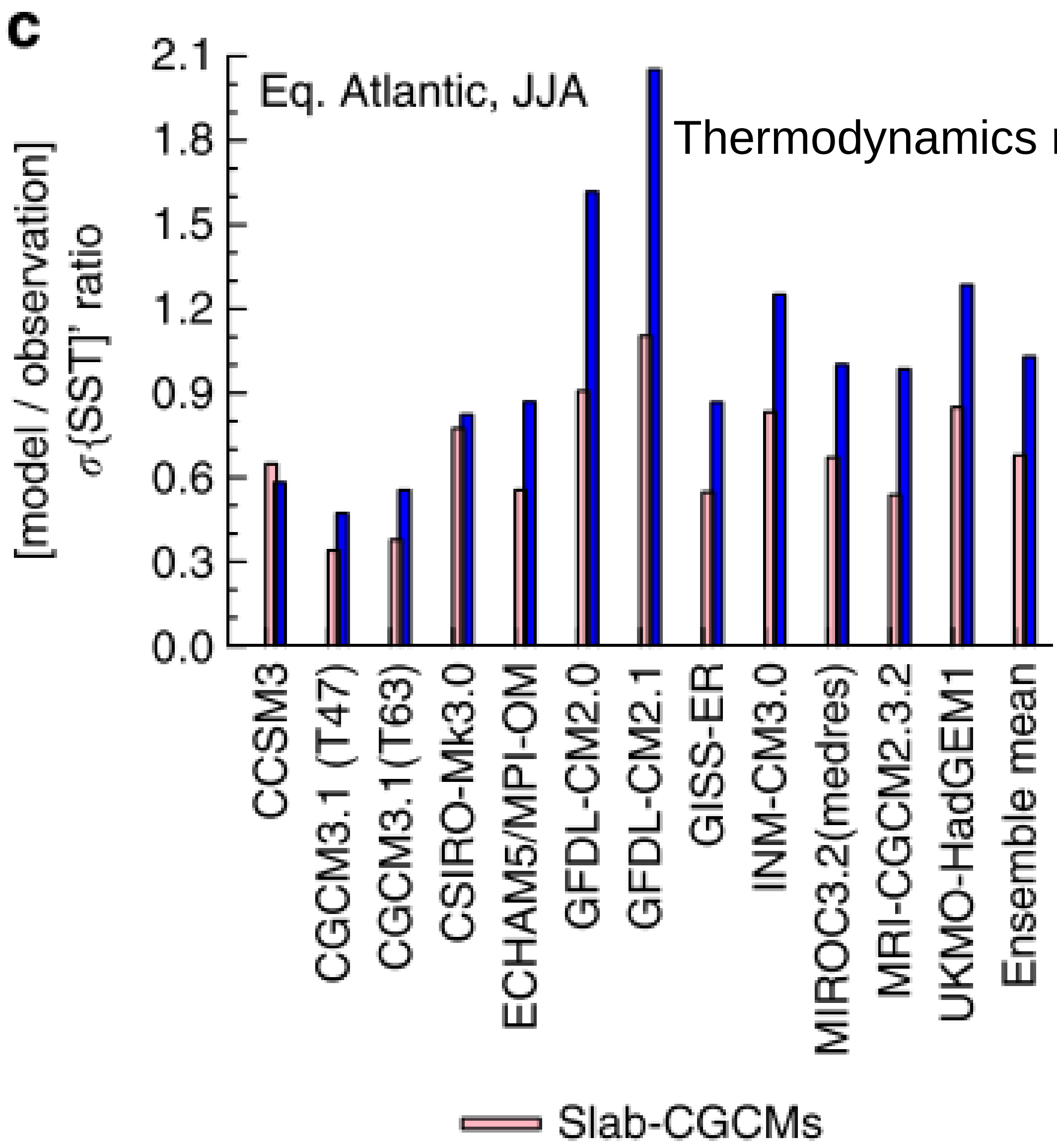
Atlantic Niño – Bjerknes Feedback



1st rotated EOF
in the Tropical Atlantic
(Ding et al. 2015)



Atlantic Niño – Role of Thermodynamic



Thermodynamics might play a crucial role

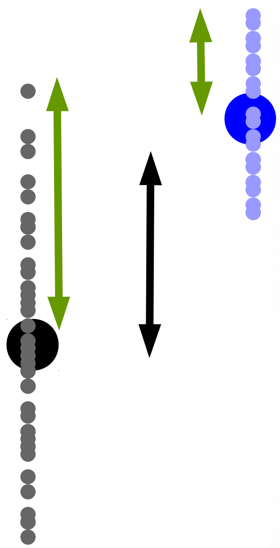
Nnamchi et al. 2015

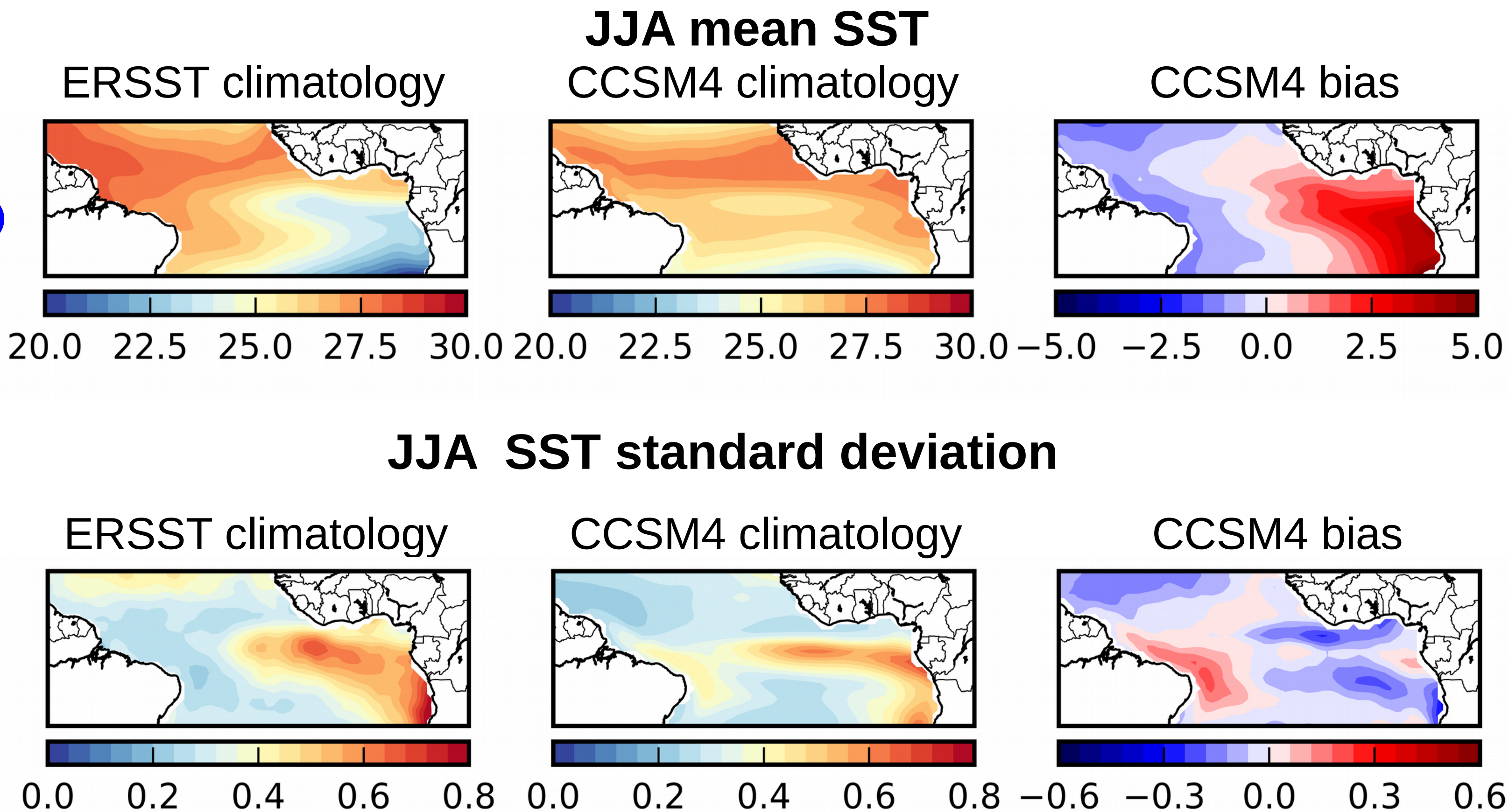
Bias and variability

Climate models try to reproduce reality, in other words to be as close as possible to the observations:

→ In terms of mean state

→ and interannual variability

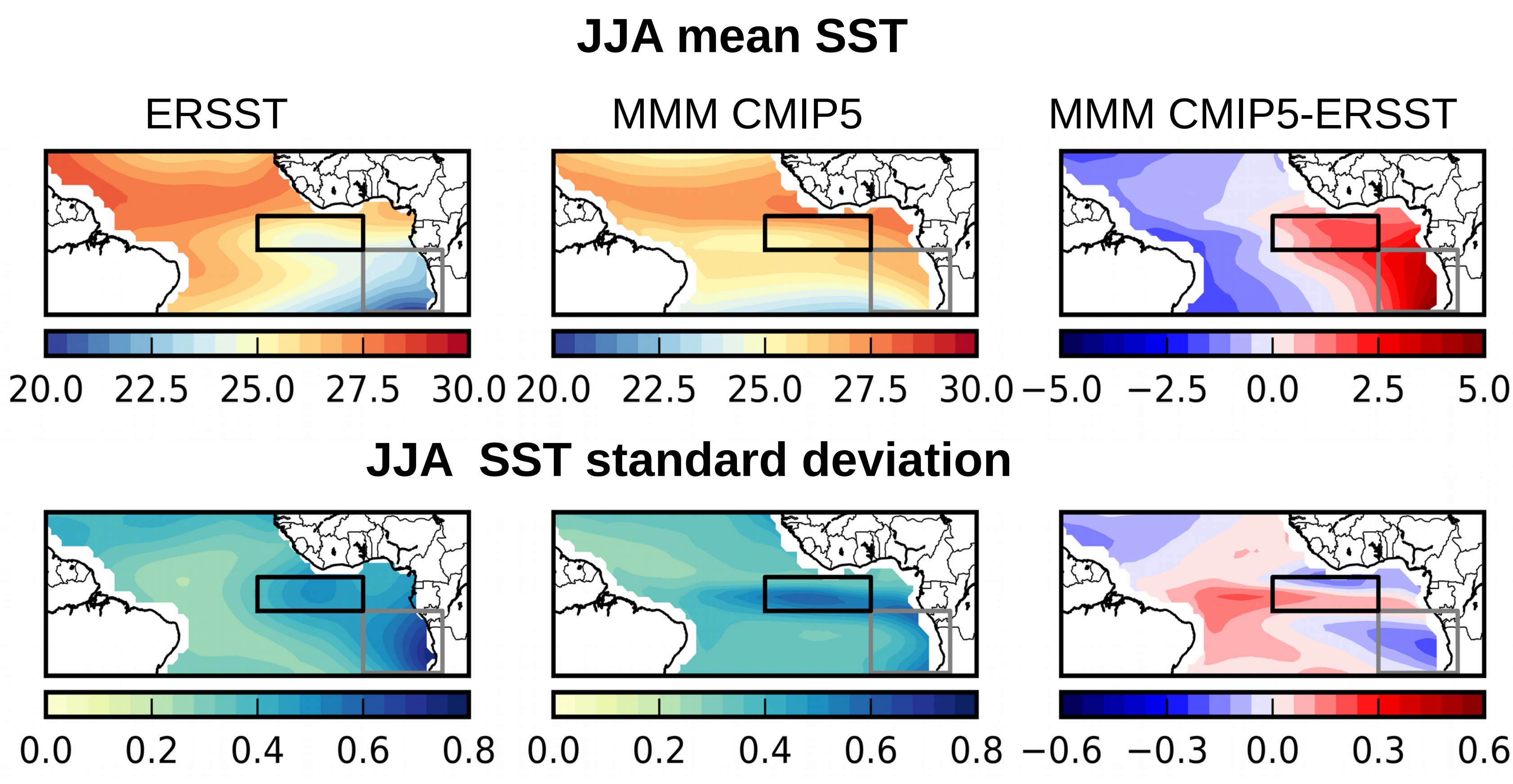




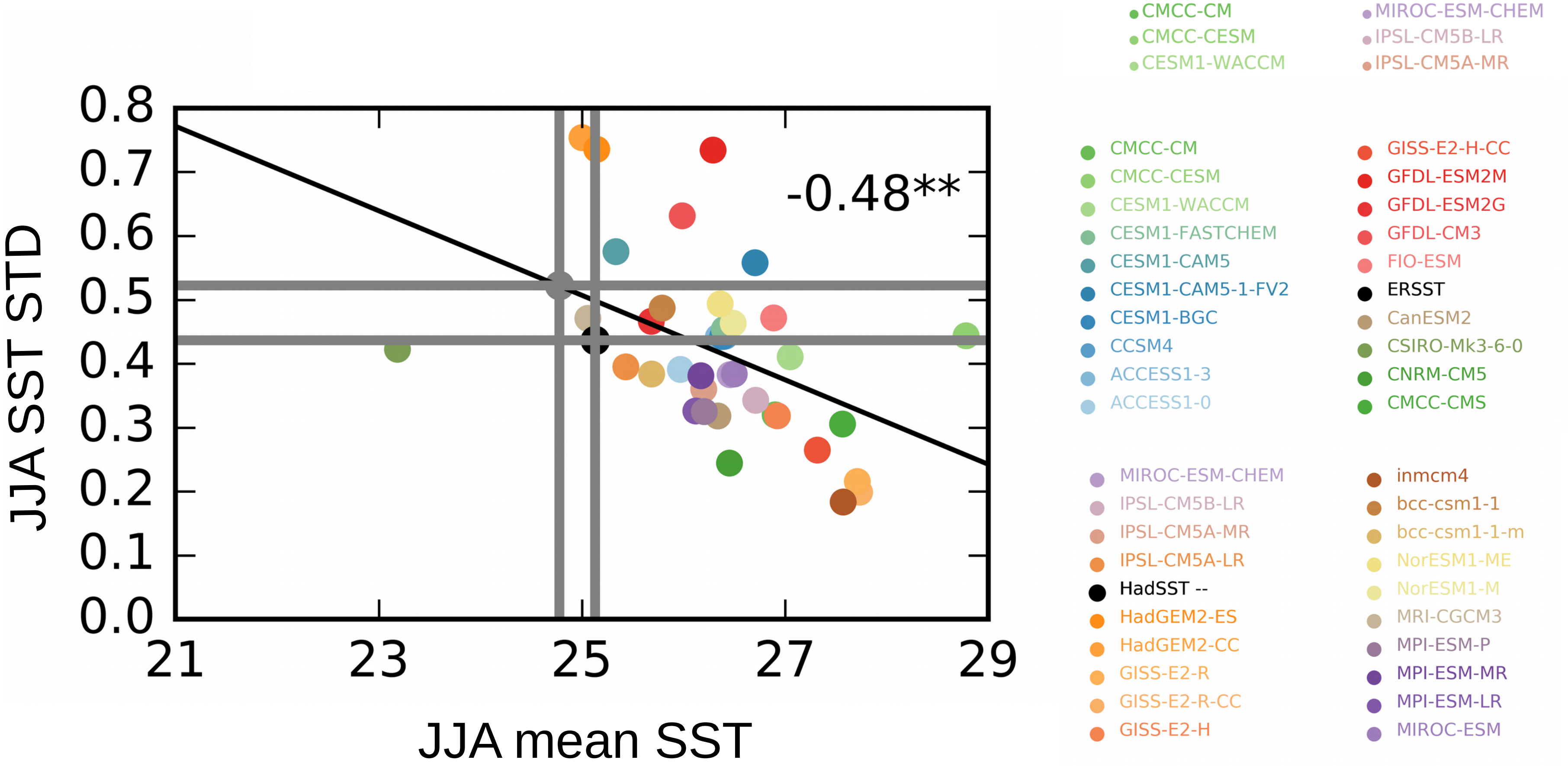
CMIP5 models

- All the CMIP5 pre-industrial simulations (38 models)
- two observational products: ERSST and HadSST (1954-2015)

GISS-E2-H-CC
GFDL-ESM2M
GFDL-ESM2G
GFDL-CM3
FIO-ESM
ERSST
CanESM2
CSIRO-Mk3-6-0
CNRM-CM5
CMCC-CMS
inmcm4
bcc-csm1-1
bcc-csm1-1-m
NorESM1-ME
NorESM1-M
MRI-CGCM3
MPI-ESM-P
MPI-ESM-MR
MPI-ESM-LR
MIROC-ESM
CMCC-CM
CMCC-CESM
CESM1-WACCM
CESM1-FASTCHEM
CESM1-CAM5
CESM1-CAM5-1-FV2
CESM1-BGC
CCSM4
ACCESS1-3
ACCESS1-0
MIROC-ESM-CHEM
IPSL-CM5B-LR
IPSL-CM5A-MR
IPSL-CM5A-LR
HadSST --
HadGEM2-ES
HadGEM2-CC
GISS-E2-R
GISS-E2-R-CC
GISS-E2-H

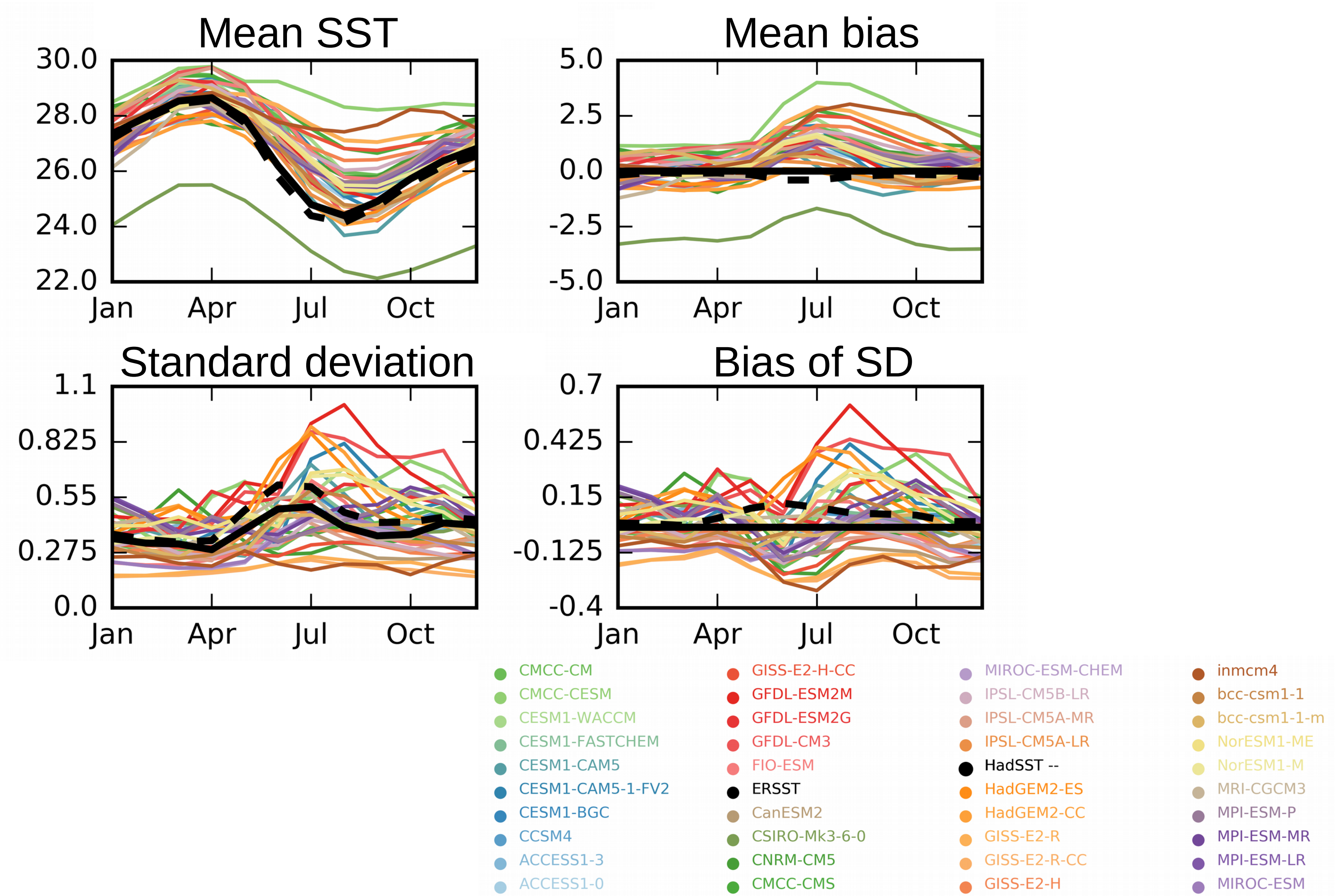


Mean state versus variability

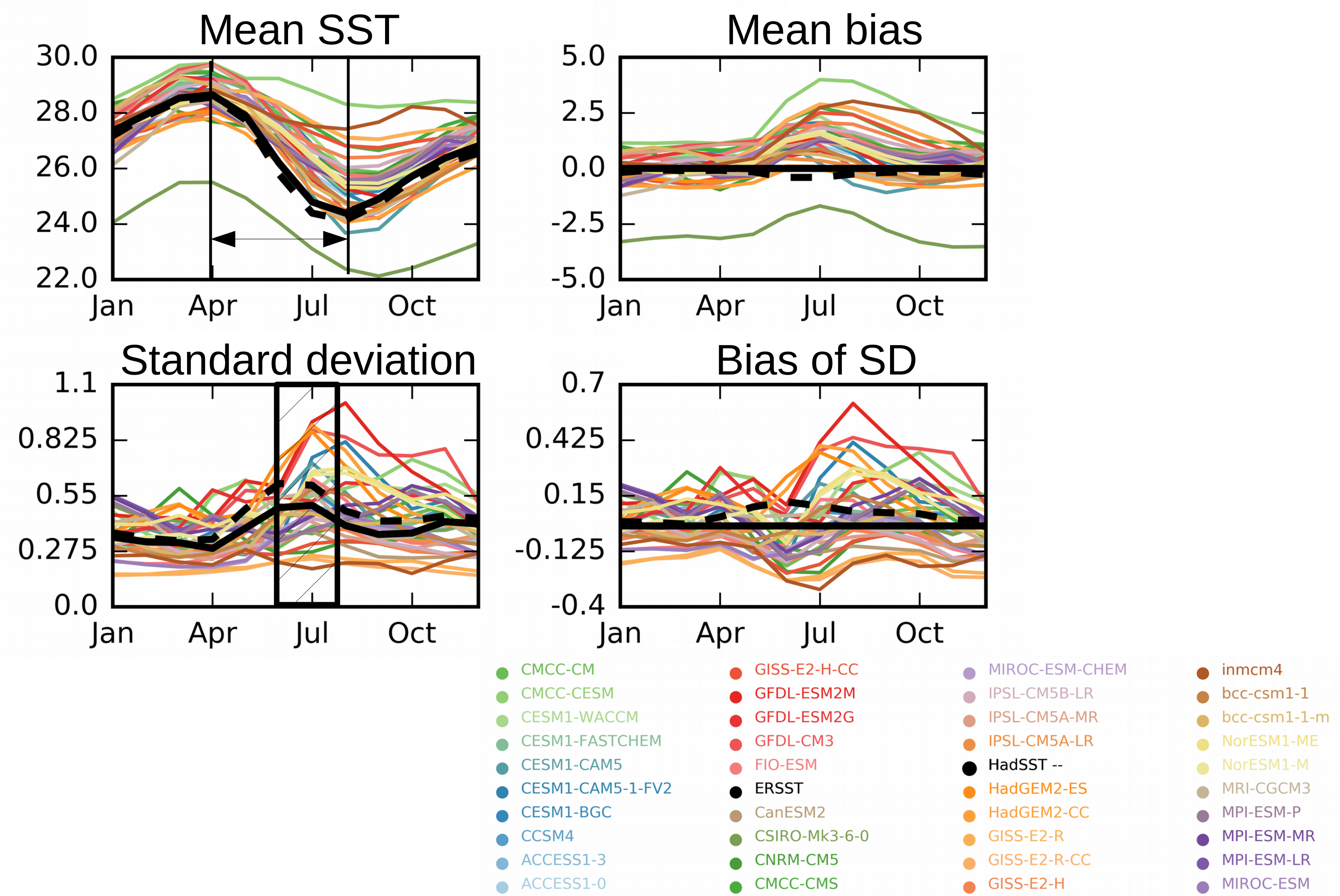


→ There is a significant relationship between the mean and standard deviation representation in Atl3.

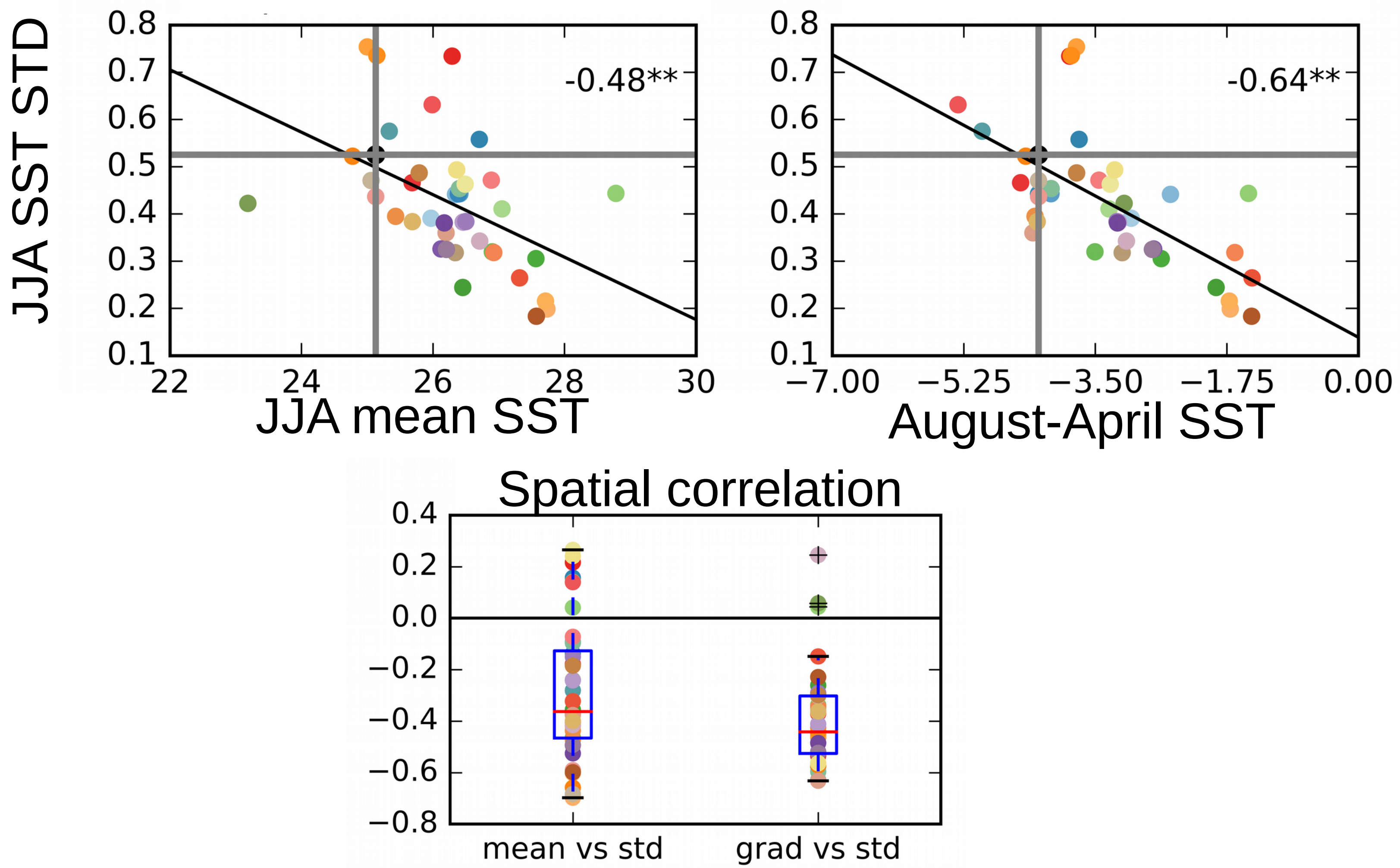
Seasonal cycle



Seasonal cycle



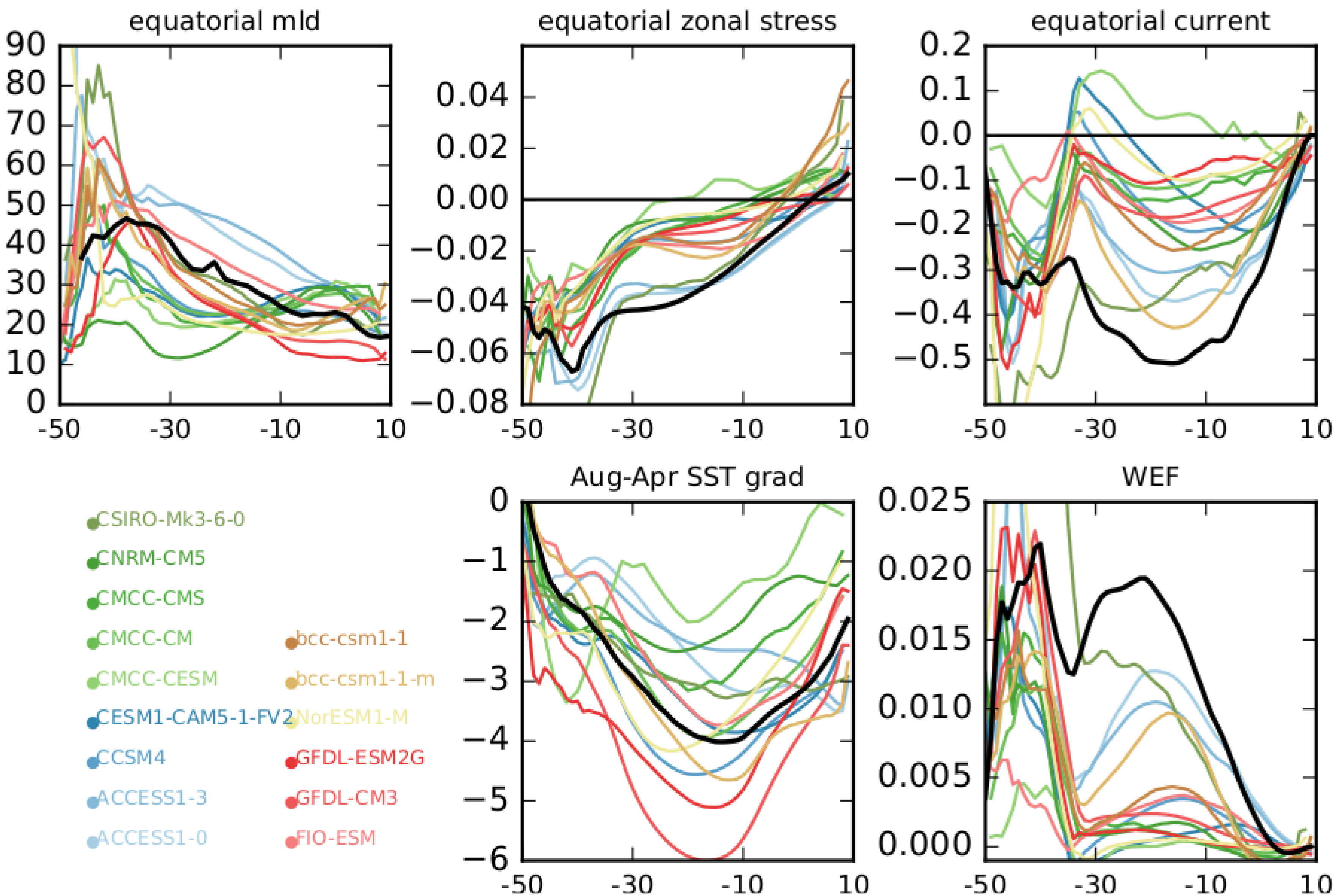
Seasonal cycle and variability



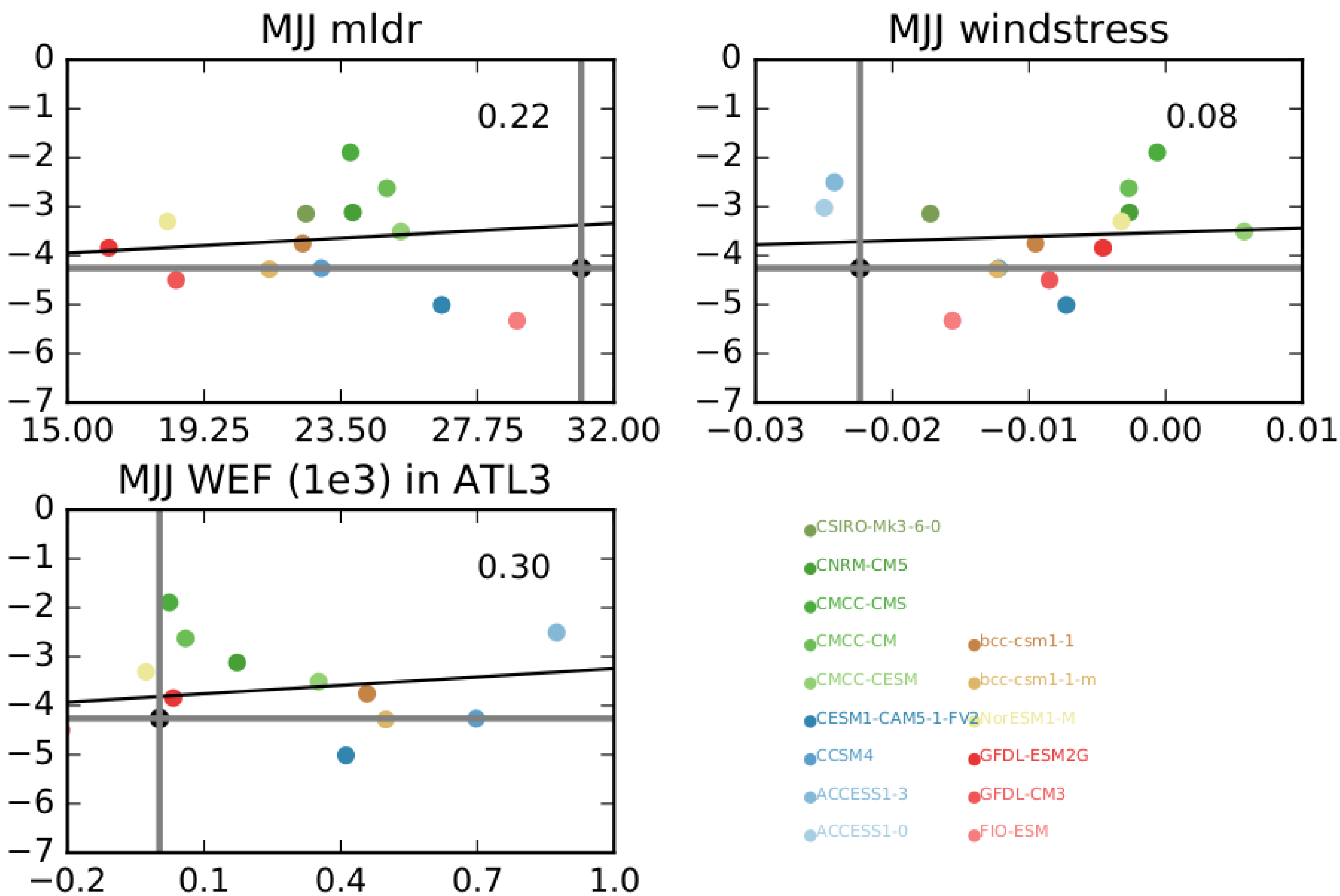
→ The ability of the model to reproduce a correct interannual variability is slightly more linked to the ability to reproduce a realistic seasonal cycle than a correct mean state.

Mechanisms?

During the beginning of summer (MJJ)



Mechanisms of the cold tongue formation



Summary

→ To reproduce a correct interannual variability it is essential that the model are able to reproduce a realistic seasonal cycle.

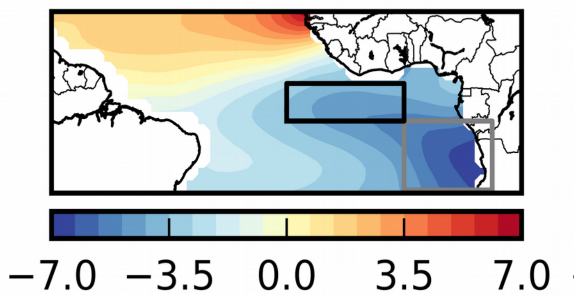
→ The variability tend to develop where the cold tongue develop.

→ The wind effect might play a role in the cold tongue development.

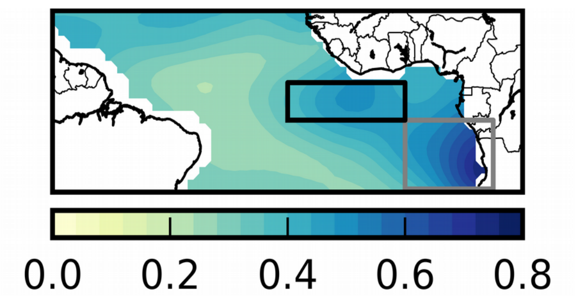
→ It appears essential to analyse the thermodynamic prossesses (on-going)

=> When performing tuning of coupled models, it might be important to pay attention to the representation of seasonal cycle.

ERSST: August-April SST



ERSST: standard deviation



How can the interanual variability of the Tropical Atlantic be predicted? Are bias limiting the predictability?

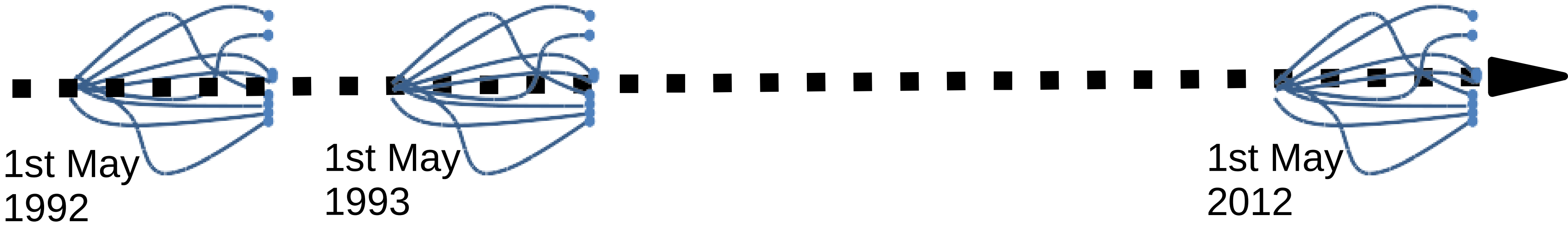
Database description

NMME + EUROSIP:

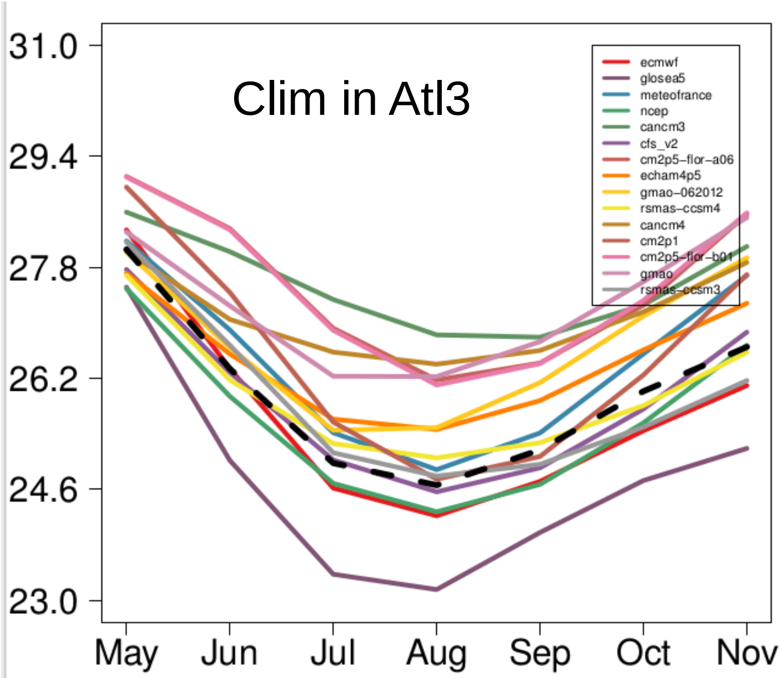
- 11 seasonal forecasts systems, over the period 1992-2012

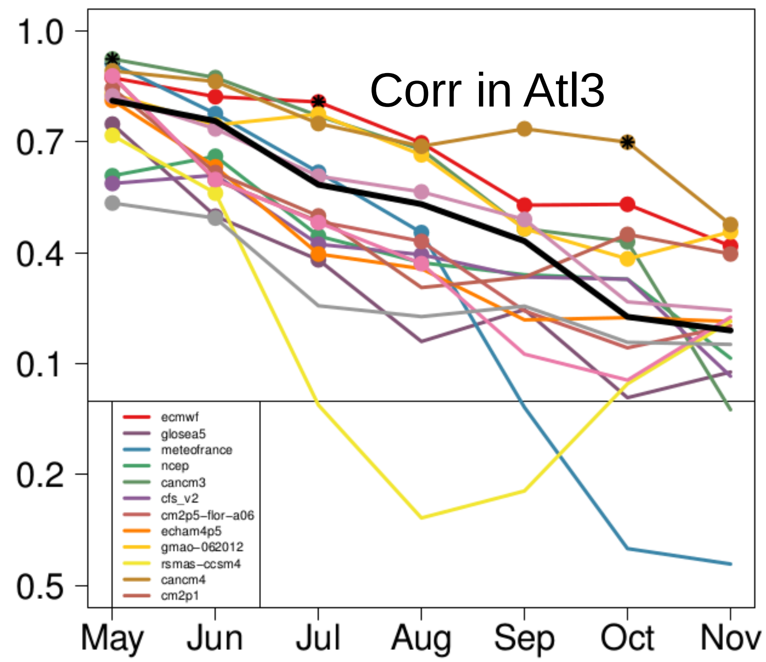
- Start dates every months (we focus on Feb, March, April, **May**)

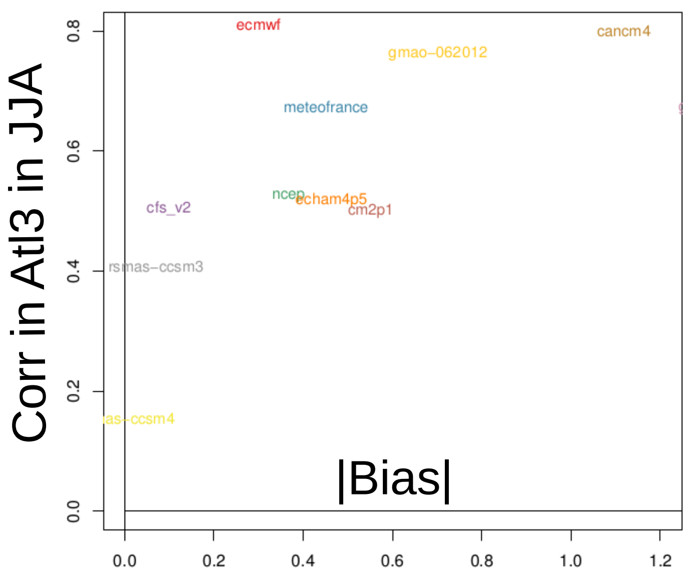
- 7 months long



Relation between biases and skill







Conclusion and questions

→ The bias in the southeast Tropical Atlantic is related to misrepresentation of low-level cloud and associated error in solar fluxes.

→ To reproduce a correct interannual variability it is essential that the models are able to reproduce a realistic seasonal cycle.

→ Some seasonal forecast systems do have skill above persistence in the Tropical Atlantic

→ The skill does not seems to linked with the strength of the drift.

→ What is the role of thermodynamics processes in the formation of the cold tongue? And in the representation of the variability in CMIP5?

→ What are the processes explaining skill above persistence in seasonal forecasts?

www.bsc.es

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Thank you!

Chloe.prodhomme@bsc.es

Message and prospects....

=> When performing tuning of coupled models, it might be important to pay attention to the representation of seasonal cycle and not only to the mean state representation.

What are the mechanisms relating seasonal cycle and Atlantic Niño?

Prospects coming from the session OS1.6/CL2.11:

→ Investigate mixed-layer depth and thermocline seasonal evolution.
→ representation of the Bjerkness feedback.
→ Northward migration of the ITCZ and associated wind background.
→ Remote biases.

Could we find similar relations in other regions of large variability?

REFUGEES WELCOME